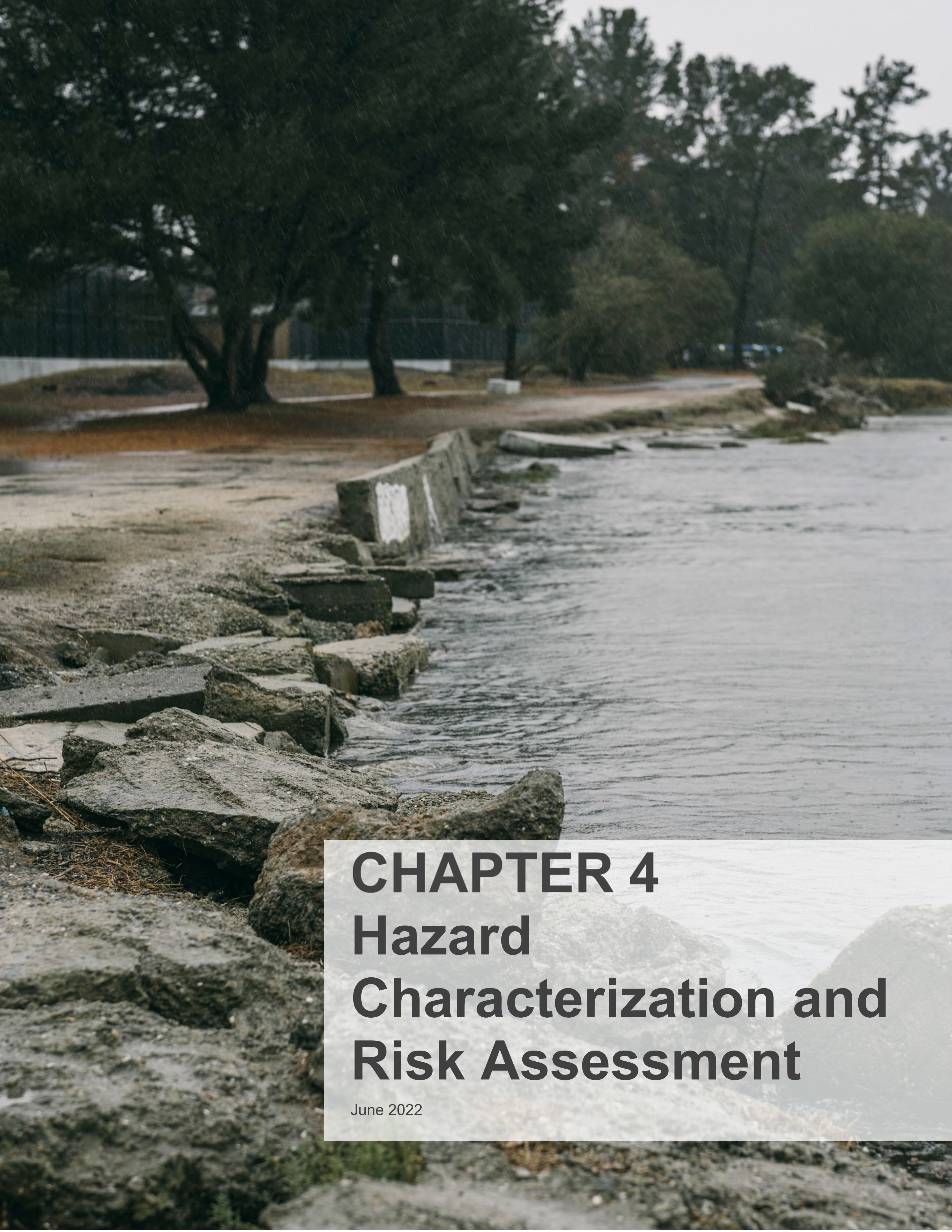


CHAPTER 4 Hazard Characterization and Risk Assessment

June 2022

Review of Hazards

Alameda is impacted by a number of natural hazards that have the potential to significantly disrupt daily life and cause damage to people and property. This chapter provides an overview of the hazards that impact Alameda and assesses the risks they pose to Alameda's people, economy, buildings, and infrastructure.

Hazards impacting Alameda that were considered in the plan were reviewed and assessed based on their likelihood of future occurrence and their consequences to Alameda's people and assets if the hazard were to occur. **Table 4-1** provides a summary of the hazards considered and their relative likelihood and consequence. Based on this analysis, it was determined that earthquakes, floods and sea level rise pose the greatest risk to people and property in Alameda. Other hazards may also have significant impacts but are less likely to occur, or the consequences may be more limited in duration or impact. These hazards are still considered and addressed in the context of this plan, but the primary focus of the plan is on the three hazards of greatest concern.

Table 4-1 Summary of Hazard Analysis

Hazard	Likelihood	Consequence	Hazards of Concern
Earthquakes	Likely	Catastrophic	Hazards of Greatest Concern
Flooding from storms	Likely	Moderate to Catastrophic	
Sea level rise	Likely	Catastrophic	
Tsunamis	Possible	Moderate to Catastrophic	Hazards of Concern
Heat	Likely	Moderate	
Drought	Likely	Moderate	
Wildfire-related hazards (smoky air, PSPS)	Likely	Moderate	
Dam breach inundation	Unlikely	Moderate	

This risk posed by natural hazards can be defined as the consequence of the interaction between a hazard and the characteristics that make people, and places vulnerable and exposed (UNDRR Terminology, 2017).

This chapter provides a brief description of the risk posed by each hazard. For hazards of greatest concern, the following appendices provide additional details on the analysis, including exposure of assets to hazards:

- Appendix E: Detailed Earthquake Risk Assessment
- Appendix F: Detailed Flooding and Sea Level Rise Risk Assessment
- Appendix G: Priority Coastal Inundation Locations
- Appendix H: Additional Maps
- Appendix I: Tsunami Table

Earthquakes

An earthquake is the hazard most likely to cause rapid, extensive damage in Alameda. This damage will primarily result from violent shaking and ground disturbances. Other hazards association with earthquakes such as fault rupture and landslides are not possible for Alameda. The perceived intensity of an earthquake is related to the energy released by the earthquake (its magnitude), how close it is, and the underlying soil conditions. Bay Farm Island and Alameda Island consist of central cores of higher ground that are relatively stable, and surrounding areas of man-made fill or "made-ground" that can amplify shaking and liquefy in earthquakes.

In addition to the damage to Alameda itself, the city depends upon its mainland connections for transportation, utilities, commerce, and services. Major damage to Oakland, San Leandro, and adjacent cities would have an indirect impact on Alameda in both the short term and long-term recovery of the City. After an earthquake, Alameda may experience isolation and disruption until bridges and utility crossings are restored.

Hazard Description

The total amount of energy released in an earthquake is described by the earthquake magnitude. The moment magnitude scale (abbreviated as M) is logarithmic; the energy released by an earthquake increases logarithmically with each step of magnitude. For example, the 1906 San Andreas earthquake, M7.8, released 500 times more energy than the 2014 South Napa Quake, M6.0. But fortunately, the frequency of large earthquakes is much less than that of smaller earthquakes. "Strong" earthquakes, M6.0-6.9, occur about 120 times per year somewhere in the world, "major" earthquakes, M7.0-7.9 occur about 18 times per year, and a "great" quake of M8.0 or more is likely to occur only once in the world per year. Fortunately, the types of faults in the Bay Area (strike/slip) are unlikely to produce quakes larger than M8.0. Farther up the coast in Oregon, Washington and Alaska, with subduction faults, M9.0 quakes are possible. When subduction zone earthquakes occur offshore, they may also produce tsunamis, which can impact Alameda.

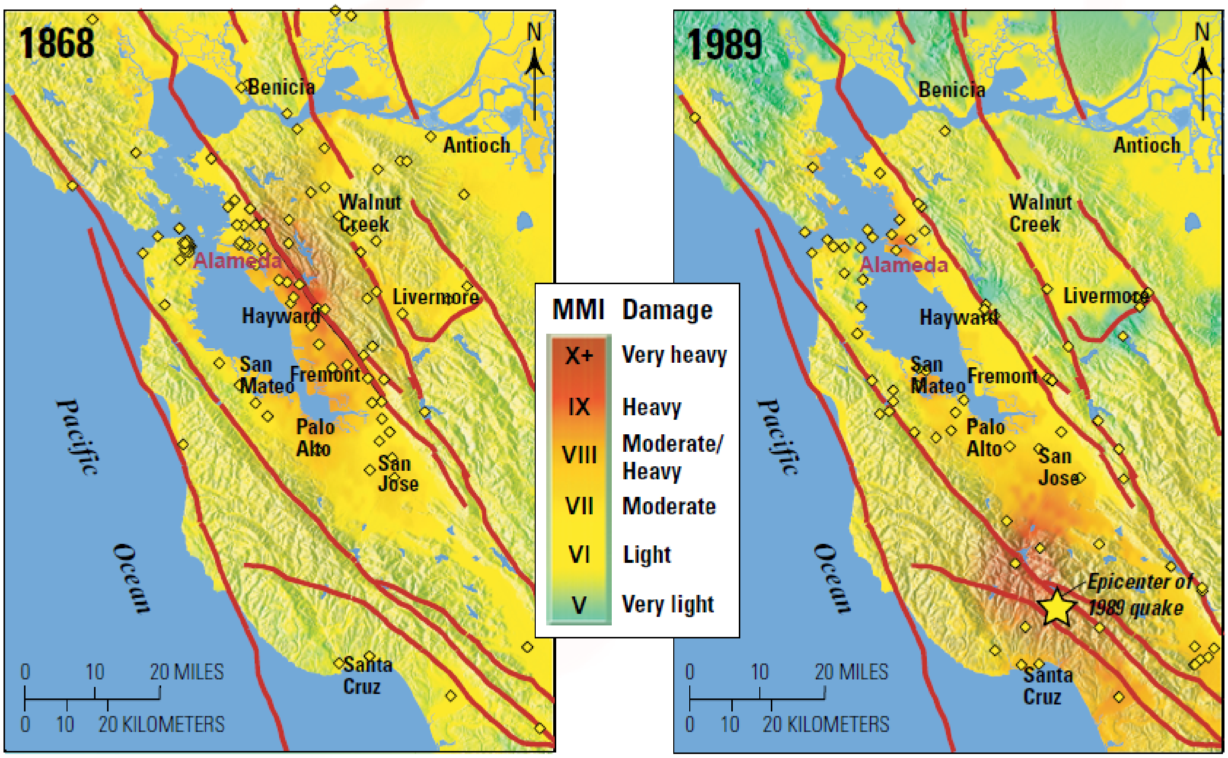
Earthquakes with the same magnitude of energy released can have different effects on nearby facilities, depending upon how close the rupture is, direction of the rupture, and the type of soil at the site. The Modified Mercalli Intensity (MMI) scale illustrates the intensity of shaking experienced at a particular location by considering the effects on people, objects, and buildings. The MMI scale describes shaking intensity on a scale of 1-12. MMI values less than 5 don't typically cause significant damage; MMI values greater than 10 have never been recorded. The USGS makes shake maps that show the MMI in areas surrounding the epicenter of an actual or scenario earthquake. **Table 4-2** below shows the expected damage caused by various MMIs.

The worst-case scenario for Alameda is a major earthquake along the southern portion of the Hayward Fault, because that is the closest fault to Alameda, only four miles away. A major earthquake on any one of the faults in the Bay Area is predicted to cause at least some ground disturbance on the made-ground portions of Alameda. Made-ground is much more sensitive to shaking and ground disturbance. Shaking is likely to be felt all over Alameda, but more violently on made-ground. **Figure 4-1** shows shake maps showing the MMI of ground shaking for the historic magnitude M 6.9 quakes in 1868 on the Hayward Fault and the 1989 Loma Prieta earthquake on the San Andreas fault. In places, Alameda experienced MMI 8 (very strong) to 9 (violent) intensity shaking during these two quakes.

Table 4-2. MMI Intensity Table

Intensity	Building Contents	Masonry Buildings	Multi-Family Wood-Frame Buildings	1&2 Story Wood-Frame Buildings
MMI 6	Some things thrown from shelves, pictures shifted, water thrown from pools	Some walls and parapets of poorly constructed buildings crack.	Some drywall cracks.	Some chimneys are damaged, some drywall cracks. Some slab foundations, patios, and garage floors slightly crack.
MMI 7	Many things thrown from walls and shelves. Furniture is shifted.	Poorly constructed buildings are damaged and some well-constructed buildings crack. Cornices and unbraced parapets fall.	Plaster cracks, particularly at inside corners of buildings. Some soft-story buildings strain at the first-floor level. Some partitions deform.	Many chimneys are broken and some collapse, damaging roofs, interiors, and porches. Weak foundations can be damaged.
MMI 8	Nearly everything thrown down from shelves, cabinets, and walls. Furniture overturned.	Poorly constructed buildings suffer partial or full collapse. Some well-constructed buildings are damaged. Unreinforced walls fall.	Soft-story buildings are displaced out of plumb and partially collapse. Loose partition walls are damaged and may fail. Some pipes break.	Houses shift if they are not bolted to the foundation, or are displaced and partially collapse if cripple walls are not braced. Structural elements such as beams, joists, and foundations are damaged. Some pipes break.
MMI 9	Only very well anchored contents remain in place.	Poorly constructed buildings collapse. Well-constructed buildings are heavily damaged. Retrofitted buildings damaged.	Soft-story buildings partially or completely collapse. Some well-constructed buildings are damaged.	Poorly constructed buildings are heavily damaged, some partially collapse. Some well-constructed buildings are damaged.
MMI 10	Only very well anchored contents remain in place.	Retrofitted buildings are heavily damaged, and some partially collapse.	Many well-constructed buildings are damaged.	Well-constructed buildings are damaged.

Source: ABAG, 2013, Modified Mercalli Intensity Scale



A ShakeMap showing the inferred intensity of ground shaking in the 1868 earthquake (measured as MMI, or Modified Mercalli Intensity), compared to a ShakeMap for the 1989 magnitude 6.9 Loma Prieta earthquake. Red lines are major earthquake faults; black line shows the portion of the Hayward Fault that ruptured in 1868; diamonds show locations of damage reports (1868) and seismic recordings (1989).

Figure 4-1 Shake Maps Comparing Damage from the 1868 Hayward Earthquake (approx. M6.9) to the 1989 Loma Prieta Earthquake (M6.9)

Earthquake Liquefaction

Earthquakes can cause ground disturbances, including liquefaction and subsidence. Liquefaction occurs when the underlying saturated sands and muds lose strength and liquefy during shaking and may even come to the surface as mud boils. Subsidence happens when small pockets or whole neighborhoods sink down permanently because of the loss of strength during liquefaction. During the Loma Prieta Earthquake for example, Franciscan Way, which was built on 40-year-old made-ground, sank slightly due to liquefaction. This caused difficulties with the sanitary sewer system and necessitated the construction of a sanitary sewer pump station to boost flows from the neighborhood to the main line. The storm drain lines, while still functional, were also impaired. Several residential streets needed emergency repair due to differential settlement. Ground improvement techniques to mitigate liquefaction and subsidence, include replacement of the liquefiable soils, compaction by various techniques, grouting, deep pile mixing, gravel piles and lowering the groundwater table, all of the techniques are challenging in an already built environment. **Figure 4-2** shows areas that are highly susceptible to liquefaction throughout the city. **Appendix H** shows maps of city sewer and storm drain facilities in relation the liquefaction susceptibility. In a Hayward Fault earthquake, the areas of the city with very high liquefaction potential have an approximately 50 percent chance of liquefying, while the medium liquefaction potential areas have less than a 5 percent likelihood of liquefying.[1]

As groundwater rises with rising sea level, more areas of Alameda may become susceptible to liquefaction. For more information on rising groundwater, see the Flooding section. Because Alameda's groundwater table is already relatively high, the impact of a rising groundwater table is anticipated to be relatively minor, especially over shorter time horizons.[2]

Figure 4-2 Liquefaction Susceptibility Map

Earthquake Caused Fires

After direct losses caused by violent shaking, liquefaction and subsidence, the largest secondary effect to consider during and after an earthquake is fire. The Great Earthquake of 1906 was also known as the Great Fire of 1906, because much of the damage to San Francisco was caused by fires started by the earthquake. Post-earthquake fires can be caused by damage to natural gas lines, electrical lines, toppled water heaters, and appliances. After an earthquake, fire-fighting efforts may be hampered by the number of simultaneous fire ignitions across the city, streets blocked by rubble or trees, lack of water pressure, lack of mutual aid if Oakland and San Leandro are equally hard-hit, and loss of access across bridges. Firefighting personnel would have to be split between fighting fires and performing paramedic services.

[1] Jones, J.L., Knudsen, K.L., Wein, A.M., 2017, HayWired scenario mainshock—Liquefaction probability mapping, chap. E of Detweiler, S.T., and Wein, A.M., eds., The HayWired earthquake scenario—Earthquake hazards: U.S. Geological Survey Scientific Investigations Report 2017–5013–A–H, 126 p., https://doi.org/10.3133/sir20175013v1.
[2] Grant, A.R., at al. (Draft) Changes in Liquefaction Severity in the San Francisco Bay Area with Sea-Level Rise

In Alameda, fires following earthquakes could be very damaging due to firefighting resources being stretched thin and the dense urban environment with older wood structures likely to be damaged and the ability of fires to rapidly spread between structures. Areas that experience liquefaction are also more vulnerable to post-earthquake fires because of the greater potential for underground natural gas lines to rupture and start fires and because water lines in these areas may also be damaged by liquefaction, preventing firefighting with regular resources. Areas with hazardous materials may have the potential for explosion, fires, or toxic smoke. Laboratories are significant concern for hazardous material fires.

Other Earthquake Related Losses

In addition to the direct losses caused by earthquakes and earthquake-started fires, there are other secondary effects to consider during and after an earthquake, especially if the surrounding cities are impacted. This includes loss of circulation for emergency vehicles, evacuation, damage to buildings, lack of access to hospitals, lack of access for mutual aid outside of the City, loss of utilities such as power, water, telecom, and natural gas, generation of large quantities of debris, release of hazardous materials, and loss of population displaced by damaged housing, industry and commerce.

Since Alameda is relatively flat, it is not exposed to the earthquake hazards of seismically triggered landslides. There are no known faults running through Alameda and no history or geological evidence of fault rupture in Alameda. There is a hypothetical chance of minor sloughing along the shoreline perimeter, since much of the perimeter is built on mudflats, subject to liquefaction.

Historic Earthquakes

The Bay Area has experienced about 20 strong earthquakes and one major earthquake in the past 165 years, including the 1868 Hayward Fault quake (~M6.9) and 1906 San Andreas quake (M7.8). Those two earthquakes occurred before the infilling of made-ground in Alameda, and when the majority of buildings in Alameda were relatively flexible wood construction. The most notable damage was to the brick tower at Alameda City Hall, built in 1895 and damaged by the San Francisco earthquake in 1906. The damage was extensive enough to warrant removal of the tower in 1937.

Table 4-3 and **Table** 4-4 show the historic recorded earthquakes along the Hayward and San Andreas Faults, respectively.

Table 4-3. Recorded or Deduced Strong (M6.0+) Earthquakes along the Hayward Fault

Date	Magnitude	Notes
1315	Over M6.3	Based on geologic data
1470	Over M6.3	Based on geologic data
1630	Over M6.3	Based on geologic data
1725	Over M6.3	Based on geologic data, predates California missions
1868	M6.8 to M7	Based on geologic data, predates California missions
1984	M6.2	Morgan Hill (on nearby Calaveras Fault)

Table 4-4. Recorded Strong (M6.0+) and Major (M7.0+) Earthquakes along the San Andreas Fault

Date	Magnitude	Notes
1812	M7+	Southern California
1838	M7	Santa Cruz Mountains
1857	M7.9	Fort Tejon
1890	M6.3	Corralitos
1906	M7.8	San Andreas (San Francisco Quake)
1940	M7.1	Imperial Valley
1983	M6.5	Coalinga
1989	M6.9	Scotts Valley (Loma Prieta Quake)
1991	M6.3	Fortuna
1992	M7.2	Fortuna
2019	M6.4, M7.1	Ridgecrest sequence

The 1989 Loma Prieta earthquake, M6.9, occurred after the infilling of Alameda along South Shore, Bay Farm Island, and Alameda Point. This quake caused $2.1M damage to properties owned by the City of Alameda, including buildings, fuel tanks, broken water mains, broken sewer lines, street buckling, and bulkhead damage. The dollar amount of private properties is not included here.

The earthquake was strong enough to cause the collapse of the nearby Cypress Structure in Oakland. There were documented liquefaction (mud boils) in the made ground at Alameda Point and Harbor Bay Business Park on Bay Farm Island. Several neighborhoods including South Shore experienced buckled streets and sidewalks, and subsidence that made the sanitary sewer pipes no longer flow downhill, requiring the City to build a new sanitary sewer pump station. **Figure 4-3** shows a map of the settlement damage to streets from the Loma Prieta Earthquake. All were in areas of made ground, outside of the original shoreline. The Loma Prieta earthquake also caused damage to the Miller Sweeney Bridge at Fruitvale Avenue causing it to be shut to all vessel traffic until repaired.

The only strong quake to occur in the Bay Area since the 1989 Loma Prieta Earthquake is the 2014 South Napa Earthquake, M6.0, which caused extensive building and underground utility damage in Napa, along the rupture of the West Napa Fault. The damage was highly concentrated in the Napa area and no damage was reported in Alameda.

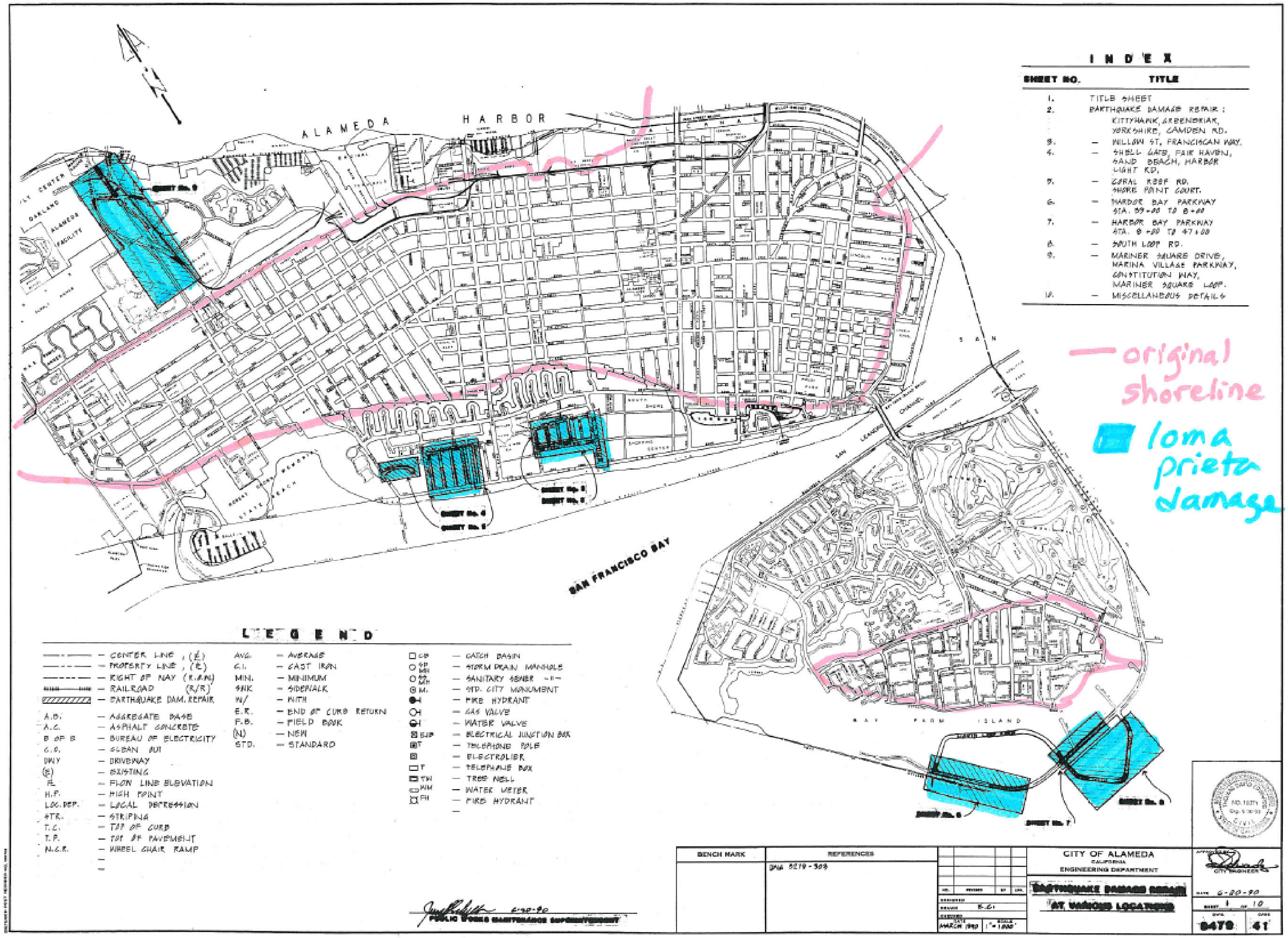


Figure 4-3 Areas of Loma Prieta Earthquake Damage and Original Shoreline of Alameda

Future Earthquakes

According to the USGS, the chance of an earthquake of M6.7 or greater somewhere in the Bay before 2043 is 72 percent.[3] As shown on **Figure 4-4**, the chance of a M6.7 or greater earthquake on our closest fault, the Hayward-Rodgers Creek Fault, before 2043 is 33 percent. The likelihood of an earthquake on the next closest fault, the San Andreas, is 22 percent.

The California Integrated Seismic Network has developed scenario earthquakes and has shown what areas will be affected by each earthquake. A M6.8 quake on the Hayward fault or a M7.2 quake on the San Andreas fault is likely to cause at least a “strong” or MMI 7 shaking in Alameda. Combining all likely scenarios on nearby faults, Alameda has a 10 percent chance of experiencing “Very Strong” to “Violent” (MMI 8 to MMI 9) shaking in the next 50 years. This probability can also be expressed as a 0.2 percent chance per year, or a 500-year event, which could happen any time. **Figure 4-5** portrays this probabilistic seismic hazard.

Strong earthquakes strike the Hayward Fault at approximately 140-year intervals, with the last major one in 1868, so we may be due for another strong quake in the relative short term. USGS developed the HayWired earthquake scenario to depict a scientifically realistic depiction of a moment magnitude (Mw) 7.0 earthquake on the Hayward Fault with an epicenter in Oakland. In the scenario the Hayward Fault ruptures for 52 miles along its length. Such an earthquake would result in strong shaking that will trigger surface fault rupture, liquefaction, landslides, fires, and severe impacts throughout the entire Bay Area. **Appendix E** describes these impacts in greater detail. The HayWired scenario represents an earthquake with approximately a 150-year return period; one that has about a 20 percent chance of occurring in the next 30 years. While the impacts of this scenario are severe, it does not represent the worst-case earthquake by any means. By comparison, most newer buildings today are designed to protect the safety of occupants in earthquake shaking with approximately a 975-year return period, or a 2 percent change of occurring in any 50-year period.

[3] Earthquake Outlook for the San Francisco Bay Region 2014–2043, USGS Fact Sheet 2016-3026. Available at https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf.

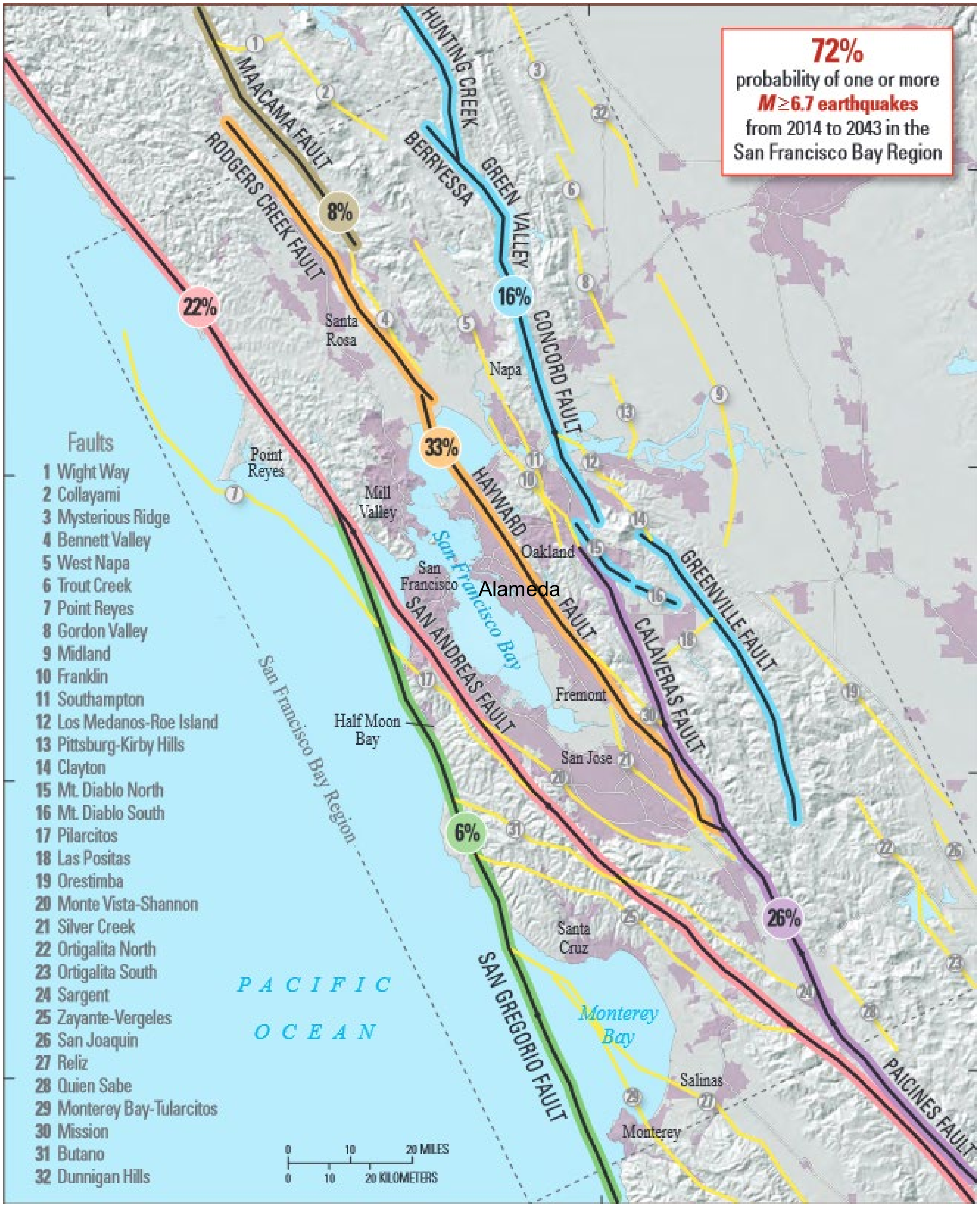


Figure 4-4 Probability that a magnitude 6.7 or greater earthquake will occur on the Bay Area fault system before 2043

Figure 4-5 Probabilistic Earthquake Shaking Hazard Map

Climate Adaptation and Earthquakes

Climate change is expected to have a role in earthquake hazards. Rising sea levels correspondingly cause rising groundwater levels. Soils that are more saturated with groundwater are more likely to liquefy and subside. Rising groundwater is explored in further detailed in the Future Flooding section.

Earthquake Risk Assessment

The vulnerability of Alameda assets to earthquake hazards is examined in detail in **Appendix E** and summarized below.

Certain types of buildings are more susceptible to the shaking and ground disturbances of earthquakes. Older buildings constructed before modern building codes are generally not designed to withstand earthquake shaking. Single family cripple wall, multi-family soft-story, unreinforced masonry, nonductile concrete, and tilt-up buildings are building types that are particularly vulnerable to damage in earthquakes. Alameda has an unreinforced masonry program that has resulted in the seismic retrofit of all unreinforced masonry buildings with 5+ units. Alameda also has a soft-story evaluation program that has resulted in the voluntary seismic retrofit of 159 buildings with five or more housing units; however, sixty-three buildings containing over 900 housing units remain unretrofitted.

Newer buildings constructed to current California building codes are designed protect occupant safety but do not ensure that a building will be usable after an earthquake. In a region experiencing a housing shortage, designing newer buildings to a higher standard would a faster recovery of these critical buildings and the recovery of the community as whole. An additional 1 percent in construction cost to build new buildings to a "functional recovery standard" could increase the availability of homes and businesses by 75 to 95 percent following a major earthquake.[4]

Buildings subject to violent shaking can also dislodge asbestos or encapsulated (abated) asbestos, lead paint, and other hazardous materials. Broken plumbing can discharge sewage. Broken gas lines and damaged electrical wiring can spark fires and present health and safety hazards. Other hazards from shaking buildings include falling piping, shelving, and goods.

Some of the City's most important buildings are vulnerable to earthquake shaking because they were constructed with the building standards that pre-dated current knowledge about earthquake dynamics. The City Hall, for example, completed in 1896, lost its central bell tower during the 1906 San Francisco Earthquake. The tower was never re-built. Since then, most of the City buildings have been seismically retrofit, or have been constructed to more modern standards. Of particular concern are the 1940s era residences and hangers on Alameda Point, the former Alameda Naval Air Station, that would be subject to earthquake shaking, liquefaction, ground settlement, and flooding. The Alameda Point Master Infrastructure Plan addresses areas of redevelopment, where buildings will be constructed to modern day seismic standards and reuse areas where retrofit work may be needed.

Alameda's five estuary crossings have all be retrofitted to a "no collapse" standard, which means that while the bridge will survive without loss of life, significant repairs or replacement may be necessary. The Fruitvale railroad bridge is a collapse hazard that poses a hazard for the adjacent Miller-Sweeney bridge. Alameda is advocating for this bridge to be removed and replaced with a pedestrian/bike bridge. The City of Alameda has requested that Miller-Sweeney bridge and Bay Farm Island bridges be upgraded to a "lifeline" standard, which would allow them to be nearly immediately usable following an earthquake.

The hundreds of miles of natural gas, water, sewer, and stormwater distribution and collection lines are all at risk to damage from liquefaction. **Appendix H** shows maps of city sewer and storm drain facilities in relation the liquefaction susceptibility and shaking hazard. Neighborhoods that experience significant liquefaction may not have service restored for weeks or months. An average East Bay customer would lose water for an estimated six weeks and some will lose service for as long as six months. Water supply outages will impede fighting post-earthquake fires. Full restoration of the natural gas system can take up to six months because of the time it will take to integrity test the lines prior to repressurizing and number of qualified personnel required to relight pilot lights.[5]

Flooding

Over 23 miles of shoreline surround both the main island of Alameda and Bay Farm Island. As such, the City of Alameda is vulnerable to flooding from both coastal storms where water enters the land along the lower elevations of the shoreline and overland from rainfall within the City during and after storm events. In the near term, both are likely to be temporary in nature, limited by high tide cycles and intensity of events, with flooding likely shallow - on the order of 2 feet or less in depth. However, as climate change increases the intensity of storm events, sea levels, and groundwater levels, the depth and extent of flooding is expected to increase and may become more frequent or permanent. Today's 100-year floodplain is approximately equivalent to 3 feet of sea level rise. Coastal storm and overland flooding are not mutually exclusive. During high tides many of the city's outfalls are already under water and the pipes

[4] Haywired Earthquake Scenario, U.S. Geological Survey, 2018.
[5] Lifelines Restoration Performance Project, City and County of San Francisco, 2020.

upstream are partially full as a result. Additionally, some outfalls have chronic issues with mud deposition and their inherent capacity is already reduced. When a coastal storm event occurs, temporarily higher sea levels back up already submerged pipes even more, and as rainfall enters the pipes from upstream this capacity is diminished further. An example of recurrent flooding in the city due to the combination of rainfall and a submerged outfall is on Main Street, next to the old entrance gate for the former Naval Air Station. This location can be seen with several inches of water in the street during certain combinations of tides and storm events.

Note: In 2013 the City's storm drain outfalls were assessed visually for capacity, condition, and operation and maintenance prioritization. An updated comprehensive cleaning and condition assessment for the entire stormwater system is planned for fiscal year 2021-23.

Although there are not a significant number of recurrent flooding locations within the city, the combined factors described above may cause additional flooding issues if the storm drain system becomes overtaxed due to rising sea levels.

In some areas of the city, storm drainage is collected through pipes and flows down to a pump station. Alameda has 11 stormwater pump stations in total. In the case of pump stations, stormwater is pumped out to the Bay under pressure through a discharge line, not a gravity outfall pipe. Therefore, if the discharge line outfall is below high tide, it can still effectively pump. This is why rising sea levels will tend to have less of an effect on some portions of the city where pump stations exist, in lieu of gravity outfalls which can back up readily.

Alameda is very flat, especially in areas of made-ground, with many streets originally constructed at minimum longitudinal grade. Over time the significant number of trees along City streets has led to an abundance of heaves caused by tree roots along street gutterlines. As a result, ponding of stormwater in front of homes is frequent and recurrent, and keeping catch basin grates and culvert inlets free of clogs caused by leaves is an issue the maintenance department stays busy with during the wet season. Many homes have sump pumps below them that discharge to the gutter as well, to minimize structural damage due to the high-water table found in various parts of the city. For this reason, ponding can occur within the gutterline during the dry season.

Hazard Description

Tides

Because the Island of Alameda and Bay Farm Island have such extensive shorelines, an understanding of tidal influence is important for existing and future flood hazard characterization. The City of Alameda normally experiences tides that range from (-) 0.2 ft Mean Lower Low Water (MLLW) to 6.4 ft Mean Higher High Water (MHHW), based on the NAVD88 datum (the NAVD88 datum, or zero elevation, is approximately the same as the elevations used in local tide tables, and is the datum used in the Flood Insurance Rate Maps described below). The highest tides of the year, or "king tides", normally occur during the winter months of November thru February, and are usually about 7.4 ft NAVD88. The ten highest king tides recorded by NOAA in Alameda for the last 80 years measured 8.6 ft to 9.5 ft NAVD88 in elevation.

Coastal Flooding

In 2018 the Federal Emergency Management Agency (FEMA) published new Flood Insurance Rate Maps (FIRMs) that show approximately 2,000 Alameda properties mapped within the 100-yr flood zone, and at least 1,100 buildings (significantly more than in the previously published 2009 FIRMs). Areas within the 100-yr flood zone have a statistical 1 percent chance per year of flooding if an extreme storm event happens during an extreme high tide, though the event could feasibly happen in any year (or even multiple times within one year).

With the 2018 update, FEMA modeling shows Both AE Zones (high risk flood zone, with wave heights less than 3 ft) and VE Zones (high risk zone, with wave heights greater than 3 ft) surrounding Alameda's shorelines with varying associated Base Flood Elevations, or BFEs (the computed elevation to which the flood is anticipated to rise). Some BFEs are as high in elevation as 14 ft NAVD88. Thankfully, all of the low points in the city's shoreline that serve as entry points for coastal flooding occur in AE Zones where the BFE is limited to 10 ft NAVD88, and therefore floodwaters would extend onto city land until they meet land at that same elevation. Nearly the entire city's land-based flood zone has a BFE = 10 ft NAVD88. For context, the BFE of 10 ft NAVD88 is 2.6 ft above the yearly typical king tide described previously and could theoretically be achieved by a combination of a king tide plus a weather-related temporarily higher sea level. The updated flood mapping for Alameda is shown below and available at msc.fema.gov.

According to the FIRMs, the main island of Alameda has its most extensive coastal flood entry locations in three main areas where the City shoreline is lower in elevation than the 100-year BFE; these occur along the northern, eastern, and Alameda Point shorelines (see **Figure 4-6**). Along the northern shoreline, this entry point is approximately 1,100 ft long and located behind (north of) the Webster and Posey Tube portals. Alameda Point is the largest portion of the main island affected by the 100-yr coastal storm event (portions shown on **Figure 4-6**); to the north, floodwaters would enter along a 1.5 mile stretch along Main Street and extend toward the northwest tip of the former Naval Air Station airfield. They would also enter from the south along a 1.6 mile stretch that includes the former seaplane lagoon and federal property. Along the eastern shoreline, the entry location is approximately 350 ft long and includes the end of the Liberty Avenue right-of-way (see **Figure 4-7**).

Bay Farm Island is especially vulnerable to coastal flooding, as the lowest property elevations within the city are found here and are included within the flood zone. The issue of most importance is that flood waters can enter from multiple locations and combine into one interconnected flood zone. These entry points within city limits include the end of Veterans Court, the low point at the Lagoon System 1 North Outfall on the northern shoreline, and approximately 1,900 ft of Doolittle Drive. Additionally, flood waters originating within the City of Oakland along the 2 miles of shoreline along Doolittle Drive/SR 61 would also affect Bay Farm Island: they would flow across the airport and enter into Alameda over a stretch of 1.2 miles of Harbor Bay Parkway (the city line), inundating city properties.

While the Chuck Corica Golf Course is shown as part of the flood zone in **Figure 4-8**, it is worth noting that extensive site grading has taken place over the last few years, and now mounds are in place along its eastern perimeter and throughout its interior. The exact effect that this regrading may have on Bay Farm Island flooding scenarios is unknown (the regrading was not done for flood protection purposes or using FEMA-accreditation methodology and therefore is not reflected on the FIRMs). Regardless, floodwaters entering Bay Farm Island at the 100-yr event could potentially block Island Drive, Doolittle Drive, Harbor Bay Parkway, Ron Cowan Parkway, and the approach to the Bay Farm Island Bridge, compromising Bay Farm Island egress from both Oakland and the main island for emergency and recovery purposes.

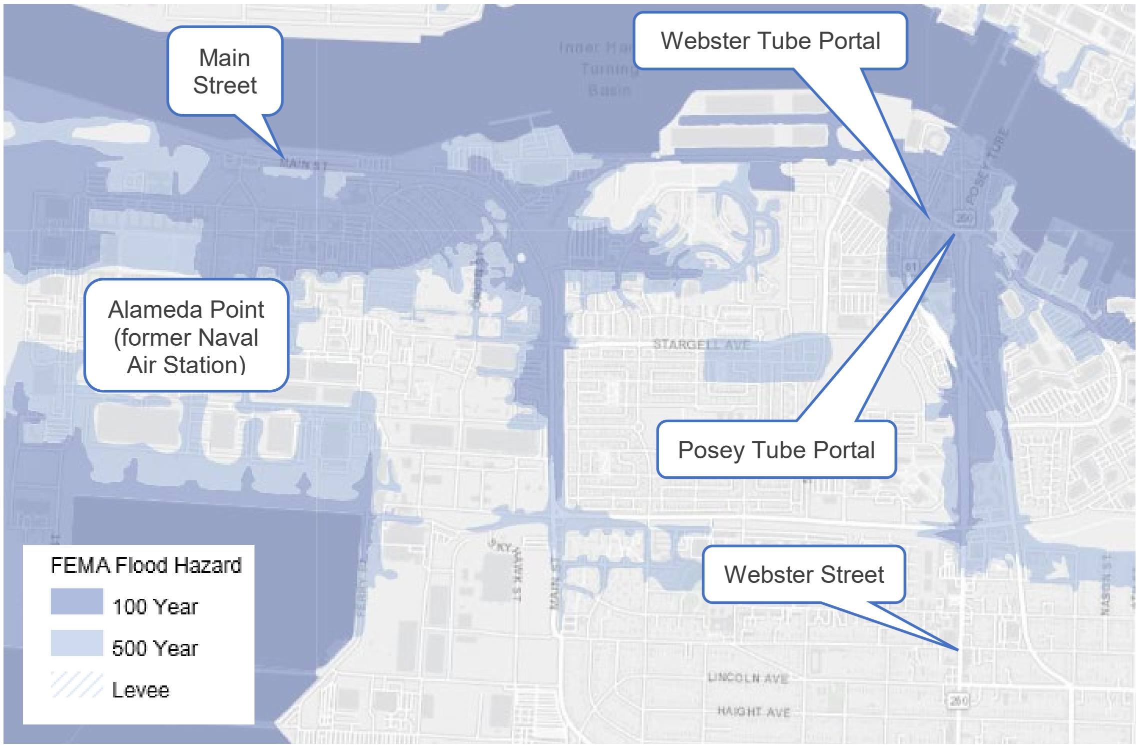


Figure 4-6 Main Island: Current (2018) FEMA Flood Mapping Along Portion of Northern and Western Shorelines. Areas affected include Webster St and Tube Portals.

Figure 4-7 Main Island: Current (2018) FEMA Flood Mapping of Eastern Shoreline. Areas affected are Liberty Avenue and Fernside Boulevard neighborhoods.

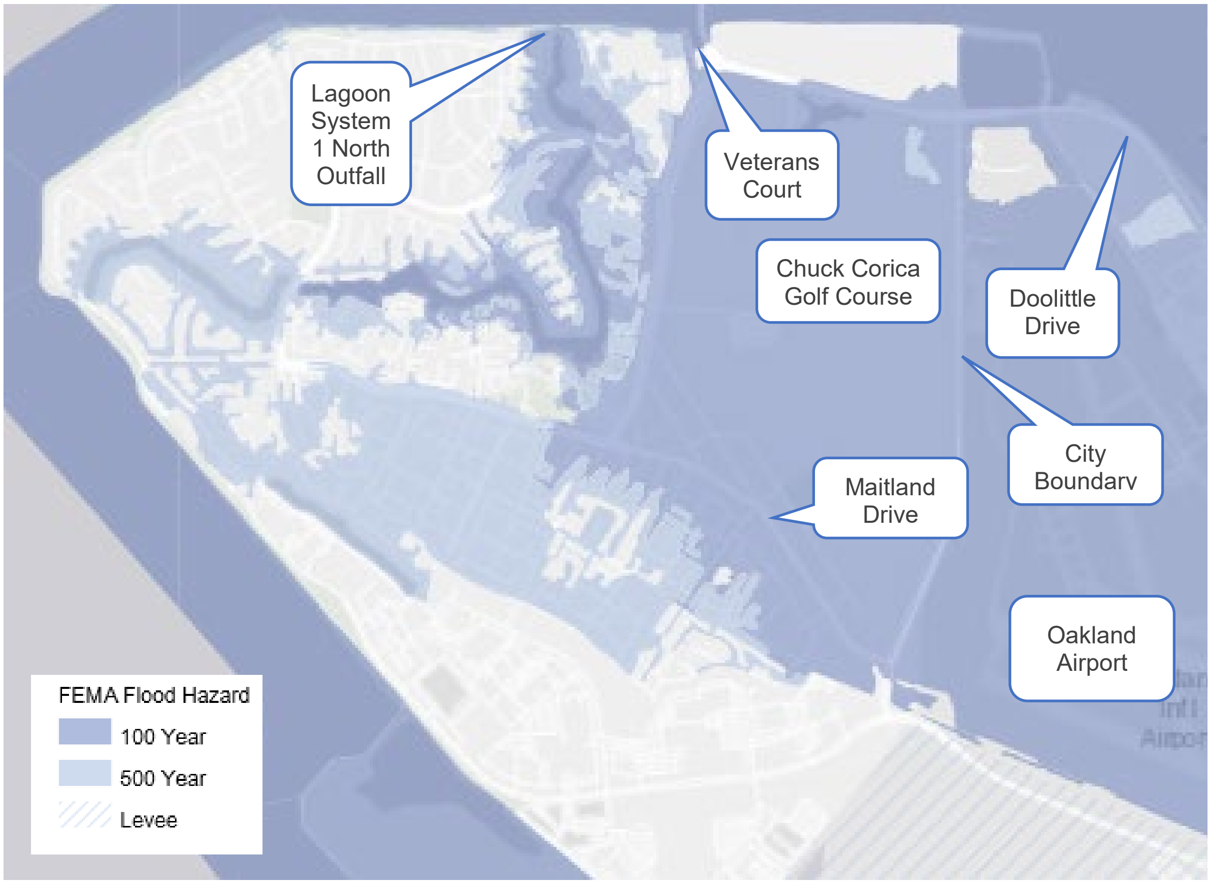


Figure 4-8 Bay Farm Island: Current (2018) FEMA Flood Mapping. Areas affected are homes along Lagoon System 1 North, Island Drive, Maitland Drive and Mecartney Road

In the above discussion, potential flooding is considered temporary – induced by storm events that have a beginning and end, and the FEMA flood maps reflect these temporary conditions. However, in the subsequent discussion on sea level rise the key difference will be that flooding conditions are considered permanent even though they may impact the same geographical area as a temporary storm today would. As such, a higher baseline sea level in the future could be considered the new "normal."

Overland Flooding

Figure 4-9 and Figure 4-10 depict modeled surface flooding in Alameda based on a historic 25-year rainstorm event. The model shows where water may overwhelm the stormwater system in a theoretical storm (these are not actual flooding locations). Red nodes indicate locations where surface flooding is expected to be greater than 1 ft in depth. Open circle nodes indicate locations expected to be 0.5 ft to 1 ft deep. Locations with less than 0.5 ft of flooding are not shown. These modeled flood nodes were used during the vulnerability assessment to specifically consider the risk of overland flooding separately from flooding due to sea level rise and storm surge.

As the figures illustrate, flooding over 1 ft deep on the main island is concentrated on the western side, along Singleton Avenue and the Webster Street corridor (and a few locations a block east or west of it). On Bay Farm Island there is only one location, at the northern end of Lagoon System 1 North. Otherwise flooding is limited to less than 1 ft at the theoretical event.

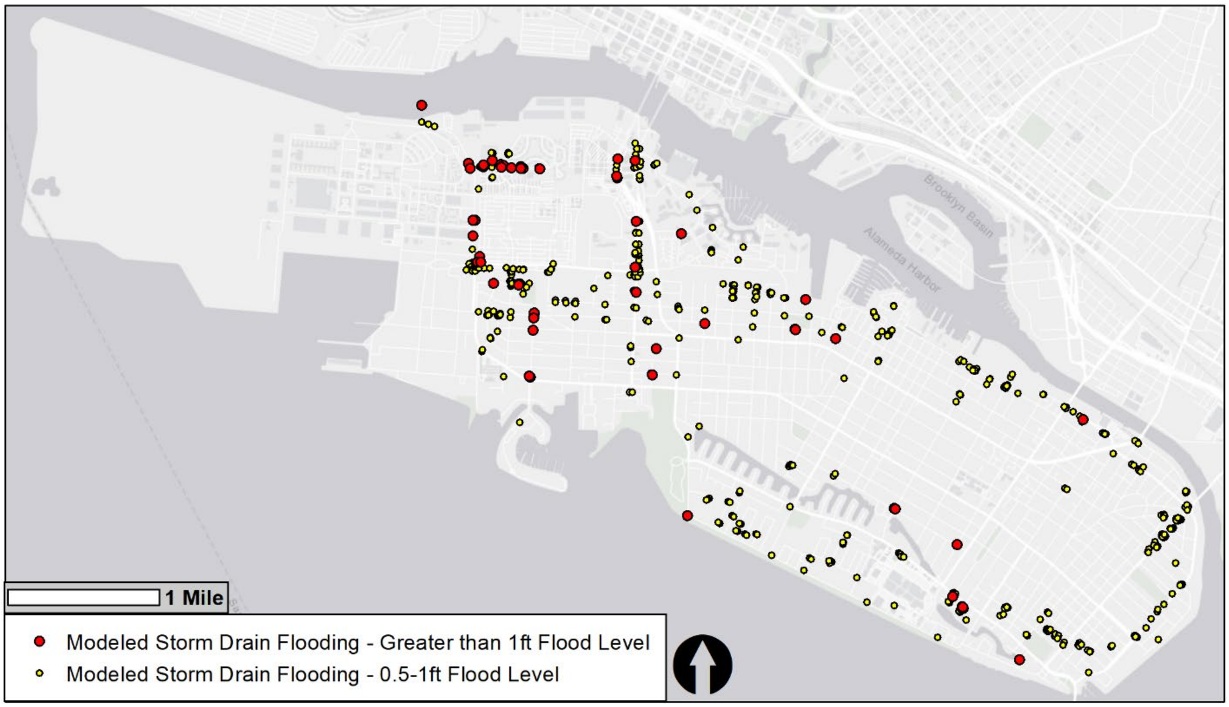


Figure 4-9 Modeled surface flooding on the main island for a 25-year storm event. Results were filtered to show only locations with modeled flood depths of greater than 0.5 ft above street level. The points shown on this map reflect model node locations

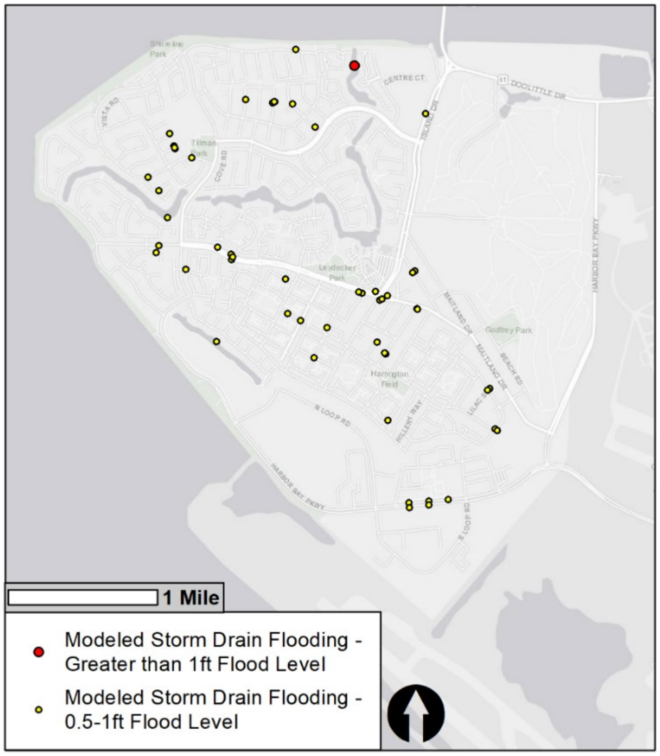


Figure 4-10 Modeled surface flooding on Bay Farm Island for a 25-year storm event. Results were filtered to show only locations with modeled flood depths of greater than 0.5 ft above street level. The points shown on this map reflect model node locations

The City has also modeled the existing stormwater collection system and determined what intersections are at risk of flooding during a 10-year storm or 25-year storm due to undersized pipes, undersized pump stations, or the inability to drain during high tides. Maps showing collection system-related flooding potential are shown in **Appendix H**. The City's storm drain modeling looked at 10 and 25-year storms, which is the normal return period used for storm drain construction.

Historic Flooding

Winter months are when the City is most likely to experience storm events. During an extreme storm event, the level of the sea can temporarily rise several feet above the level predicted by tide tables. This is caused by "wind set-up," which is the tendency for water levels to increase at the downwind shore and to decrease at the upwind shore if the storm pushes and piles up water along the coast. Temporary sea level rise can also be caused by wind-caused waves, and by the seawater increasing in volume as its temperature rises (as happens during an El Niño year) among other factors.

California experiences a megaflood, or outburst flood, event every 100 to 200 years. During the megaflood of 1861-62 that destroyed a quarter of California's economy, 28 in of rainfall fell on San Francisco in 1 month, and a record 7.76 in fell in one 24-hour period. Other areas on the West Coast experienced similarly intensity and volume. Since then, there have been less extreme flood-inducing storms every two to three years striking some part of California.

These storms are not necessarily related to El Niño or La Niña years. During normal conditions in the Pacific Ocean, trade winds blow west along the equator, taking warm water from South America towards Asia. To replace that warm water, cold water rises from the depths — a process called upwelling. El Nino and La Nina are two opposing climate patterns that break these normal conditions. During El Nino, trade winds weaken. Warm water is pushed back east, toward the west coast of the Americas. La Nina has the opposite effect of El Nino. During La Nina events, trade winds are even stronger than usual, pushing more warm water toward Asia. Off the west coast of the Americas, upwelling increases, bringing cold, nutrient-rich water to the surface.

Of the ten costliest California storm seasons between 1949 and 1997, four (1979-80, 1985-86, 1992-93, and 1996-97, in 1998 dollars) were neither El Niño nor La Niña types. The most expensive storm (1994-95) was a weak El Niño with 100-year to 1,000-year events. (J. Null, "El Niño and La Niña … Their Relationship to California Flood Damage", http://ggweather.com/enso/calif_flood.htm). Therefore, in any given year, El Niño or not, there could potentially be a severe storm. With the increased understanding and tracking of atmospheric rivers, these events will become easier to predict and prepare for.

In 1981, storms eroded Crown Beach up to the edge of Shoreline Drive. During the El Niño event of 1997-98, there was up to 2 feet of standing water on Main Street due to higher sea levels (king tide plus weather-related temporary sea level rise) and heavy rainwater runoff. And in 2006, storm waves damaged the Harbor Bay Ferry Terminal and washed away portions of the adjoining Coastal Trail. These events were relatively minor in terms of damage, and none involved structures. However, there is the potential for more extensive flooding and erosion.

The most problematic recurring flooding location in the city was alleviated in 2021, which involved construction of two relief manholes in the Crown Beach sand dune. The manholes were constructed inline with two culvert outfalls from Shoreline Drive and have their grates at a lower elevation than the catch basin grates feeding the outfalls within Shoreline Drive. This thereby prevents Shoreline Drive and Kitty

Hawk Road from flooding during a combination of large rain events and clogged outfall pipes, which maintenance crews had historically struggled with every wet season.

As of May 2021, FEMA's National Flood Insurance Program (NFIP) Claims Dashboard shows that FEMA has handled 10 flood loss claims for the City of Alameda since 1970 - a time span of 51 years. These claims have resulted in a net total payment of $30,865. There are currently no open claims, and FEMA Region IX personnel informed the City that as of May 2021 there are no Repetitive Loss (RL) or Severe Repetitive Loss (SRL) structures in the City of Alameda (Community ID# 060002) and therefore none in the identified flood hazard areas.

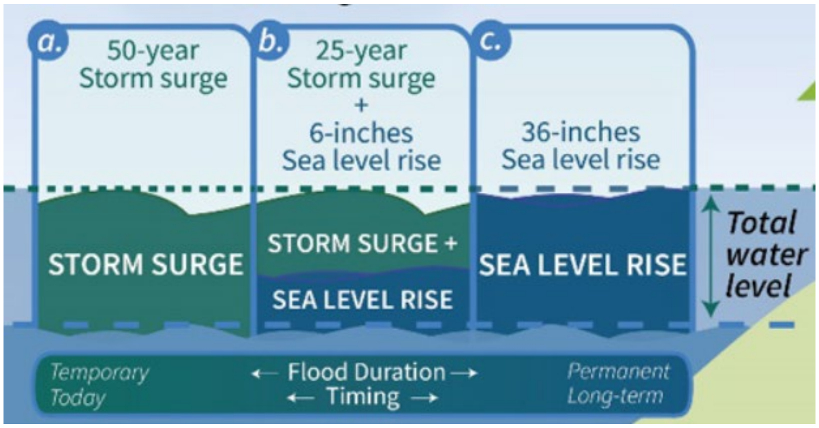
Future Flooding

Earlier, it was discussed that today's coastal flood scenario can be viewed as a potential and temporary condition, induced by a storm event that has a beginning and an end. When discussing future flooding scenarios, sea level rise may be a key difference - making flooding conditions permanent due to a higher baseline sea level. It is anticipated that future storm surge, higher sea level, and elevated groundwater levels will have a compound effect on increasing flooding scenarios within the city.

Total Water Level vs. Sea Level Rise

When discussing sea level rise, the CARP and this document evaluate tidal flooding due to storm surge and sea level rise in terms of total water level (TWL) above today's MHHW level. Using TWL recognizes the contribution of both sea level rise and storm surge to flooding and reflects a range of scenarios. For example, a total water level of 36 inches above today's high tide can result from any of the following (as shown in **Figure 4-11**):

- 50-year storm event today;
- 6 inches of sea level rise plus a 25-year storm event in the short term (6 inches sea level rise likely by 2030); and
- 36 inches of sea level rise (around 2060–2070).



(Credit: ART, San Francisco BCDC).

Figure 4-11 Image depicting total water level as a combination of sea level rise and storm surge

Applying a TWL approach enables us to plan actions that address temporary impacts of today's winter storms while simultaneously planning to address more permanent inundation from sea level rise.

Flooding Scenarios and their Timing

Table 4-5 is taken from the CARP and presents the main TWL projections shown on **Figures 4-12 and 4-13** (and referenced in the CARP) as well as additional projections, their respective elevations in NAVD88, the various flood scenarios represented by these TWLs, and the anticipated timing for these projections.

Table 4-5 Total Water Levels, Flooding Scenarios, and Timing for Sea Level Rise Projections

TWL	Elevation (NAVD88)	Flooding Scenarios: SLR + Storm Surge	Timing for SLR Projections
MHHW + 36”	~9.5 feet	50-year storm 6” SLR + 25-year storm 12” SLR + 5-year storm 18” SLR + 2-year storm 24” SLR + king tide 36” SLR	Immediate (storm risk) Before 2030 2030–2040 2040–2050 2050 2060–2070
MHHW + 42”	~10 feet (base flood elevation)	100-year storm 42” SLR	Immediate (storm risk) 2070
MHHW + 66”	~12 feet	24” SLR + 100-year storm 30” SLR + 50-year storm 36” SLR + 25-year storm 42” SLR + 5-year storm 48” SLR + 2-year storm 52” SLR + king tide 66” SLR	2050 2060 2060–2070 2070 2070+ 2070+ 2070+
MHHW + 108”	~15.5 feet	66” SLR + 100-year storm 84” SLR + 5-year storm 108” SLR	2070+ 2070+ 2070+
MHHW + 124”	~16.75 feet	84” SLR + 100-year storm	2100

Note: Sea level rise (SLR) projections correspond to medium-high risk aversion decision, high emissions scenarios from *Rising Seas in California: An Update on Sea-Level Rise Science* (Griggs et al., 2017).

California’s Ocean Protection Council, in its March 2018 Sea-Level Rise Guidance, recommends California communities plan for at least 50 years of sea-level rise at the Council’s Medium-High Risk Aversion, high emissions scenario and prepare for 100-year events at that level, such as inundation from a 100-year storm surge. For the City of Alameda, this means preparing for:

- MHHW + approximately 3.5 feet of sea level rise by 2070 plus the potential for a 3.5-foot coastal storm surge; and,
- MHHW + 5.9 to 6.9 feet of sea level rise by 2100, plus the potential for a 3.5-foot coastal storm surge.

Alameda must also consider the increased risks that 3.5 feet of sea-level and groundwater rise, as well as changing weather patterns, would bring for tsunamis, liquefaction and rainfall events.

Total Water Level Mapping

Figure 4-12 and Figure 4-13 show maps depicting inundation for four TWL scenarios: today's MHHW plus 24 in, 36 in, 77 in, and 108 in. Additionally, as described in the discussion below, while the current FIRMs show us temporary 100-yr flood conditions as of today, they also show us a TWL scenario of today's MHHW plus 42 in. Refer to **Appendix H**.

The maps show us that at a TWL of 24 in above today's MHHW, the main island can expect flooding to impact Main Street and Alameda Point, particularly the Barbers Point Road residential area to the north and the wetland/tarmac area along the southern shore. For Bay Farm Island, mainly the coastline north of Doolittle Drive is affected.

At a TWL scenario of 36 in flooding is far more extensive, and affects slightly less area than what was described previously for flood zone impacts shown on the current FIRMs (refer to Coastal Flooding section). This is because a TWL of 36 in is just a few tenths of a foot lower than the BFE shown on the FIRMs. Note: while the FIRMs represent temporary 100-yr flood conditions as of today, they also show us what the permanent flooding extent is for a TWL scenario of 42 in: MHHW + 42 in sea level rise = TWL of 10 ft NAVD88, aka area covered by the blue shown on the FIRMs.

At a TWL scenario of 77 in, the main island sees approximately three-quarters of Alameda Point flooded while northern shoreline flooding reaches as far as the Buena Vista Avenue neighborhood. The South Shore area and Crown beach is heavily inundated, and South Shore flooding connects to an also heavily inundated eastern end of the island. Bay Farm Island experiences flooding of properties along the remainder of the lagoon system as well as inundation extending southerly of Mecartney Road to a greater extent than shown on the FIRMs.

Finally, at the 108 in TWL scenario the western half of the main island is flooded as well as the entire South Shore area, East End, and northern end of the island. The central portion of the island above Elevation 15.4 ft NAVD88 remains unflooded. Bay Farm Island is approximately 80 percent flooded at this scenario, since only a select few upland areas exist above Elevation 15.7 ft NAVD88.

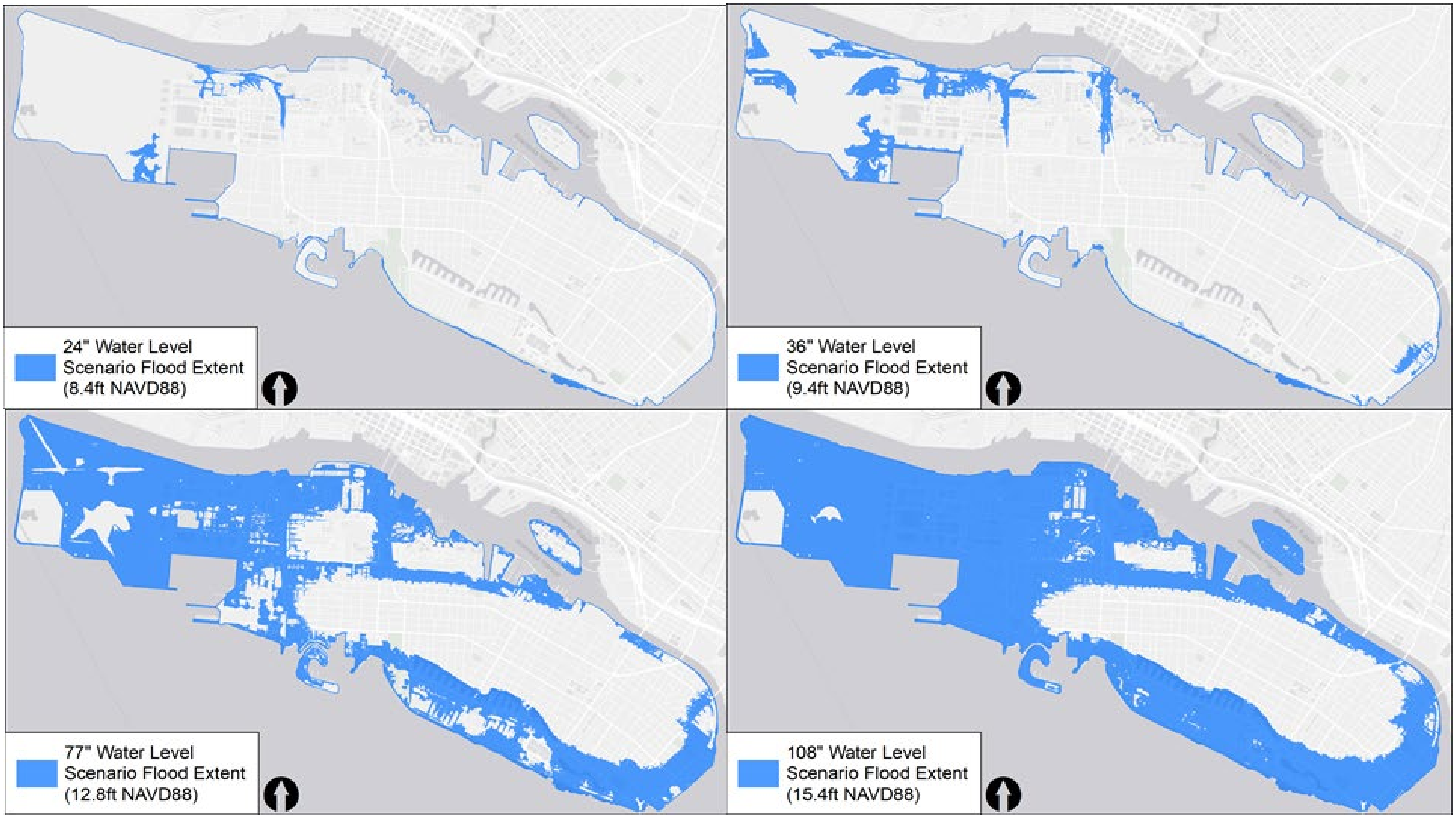


Figure 4-12 Maps depicting inundation for MHHW (6.4ft NAVD88) plus 24 in, 36 in, 77 in, and 108 in total water level scenarios for the main island.

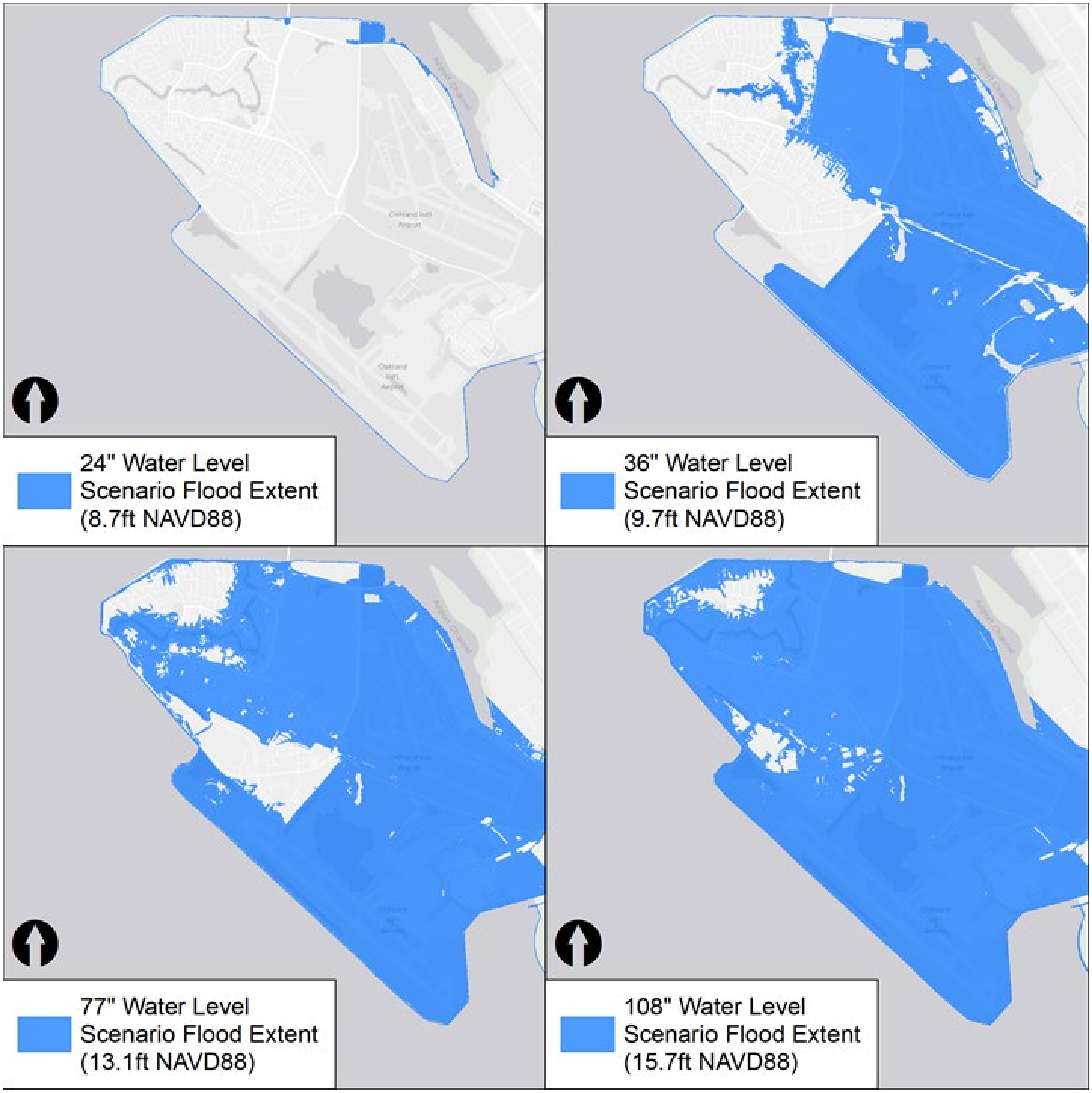


Figure 4-13 Maps depicting inundation for MHHW (6.7ft NAVD88) plus 24 in, 36 in, 77 in, and 108 in total water level scenarios for Bay Farm Island.

Impacts of Sea Level Rise on Groundwater Levels

Sea level rise can have a major impact on local and regional groundwater levels. **Figure 4-14** shows the relationship between sea level rise and groundwater in areas such as Alameda with shallow coastal aquifers. As sea level rises the freshwater lens rises as well – even in areas that are not hydrologically connected to the ocean. The magnitude of groundwater rise due to sea level rise varies based on local geology and hydrology.

Rising groundwater can damage underground assets like cables and pipes and increase the basement flooding that many Alamedans already experience (see **Figure 4-15**). Depending on the thickness of the freshwater lens and the rate of groundwater level rise, saltwater intrusion can corrode some metallic-based infrastructure materials. High groundwater levels can also reduce the efficacy and capacity of the stormwater system, potentially resulting in surface flooding.

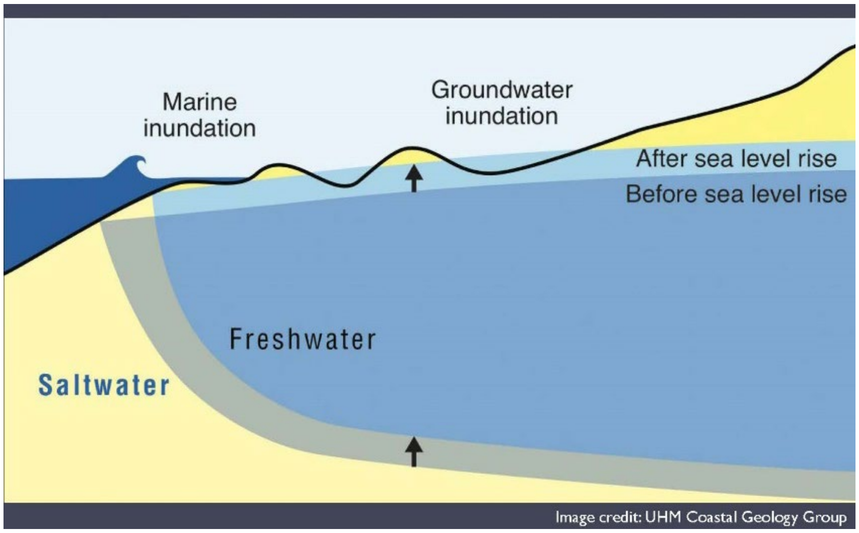


Figure 4-14 Conceptual diagram of the relationship between sea level rise and groundwater, highlighting the potential for flooding and inundation to occur in shallow areas that are not hydrologically connected to the ocean (Habel et al., 2017).

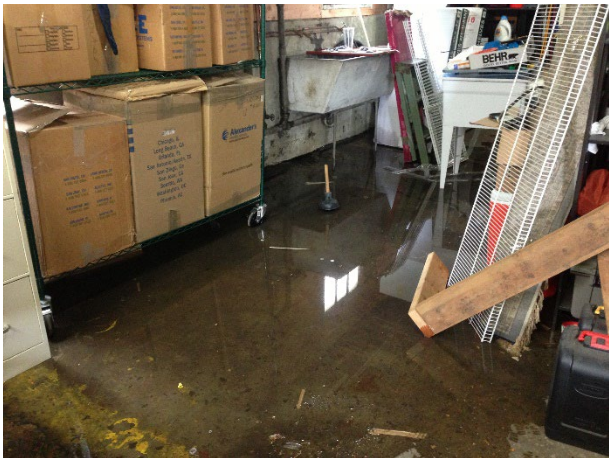


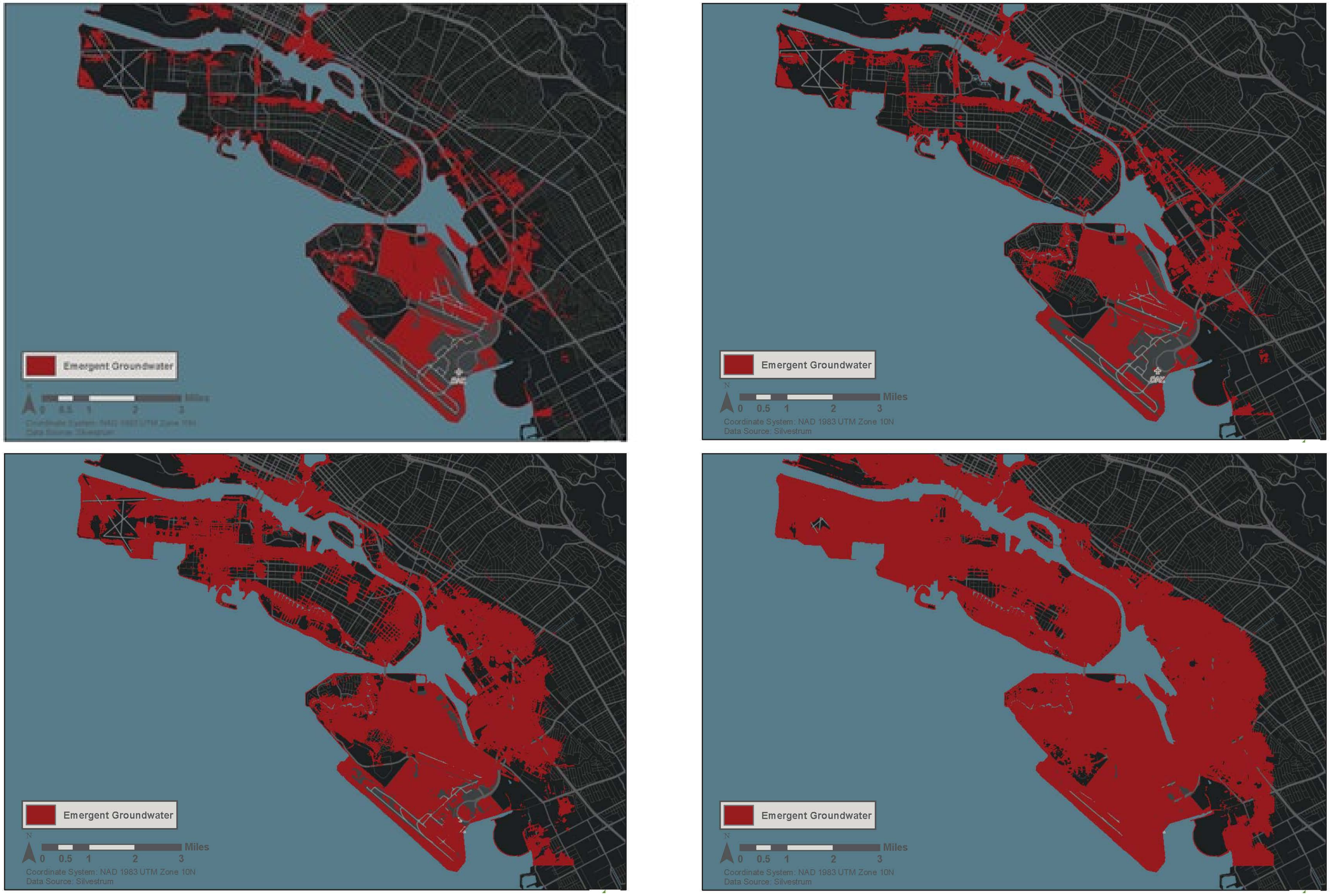
Figure 4-15 Example of basement flooding, similar to what can be found in Alameda basements. Photo Credit: Arthaey Angosii

Researchers at Silvestrum Climate Associates and the University of California, Berkeley collaborated on the development of a high level, regional shallow groundwater layer in the San Francisco Bay Area using groundwater monitoring well data. The results of the analysis, released in 2020, revealed widespread shallow groundwater conditions along most of the shore of San Francisco Bay. As sea levels rise, the groundwater surface will also rise, and these areas are at highest risk of experiencing impacts to buried infrastructure, soil behavior, human health, and nearshore ecosystems. These areas are also at risk for flooding due to emergent groundwater. The findings of this high-level assessment highlighted the need to understand the full range of sea level rise impacts for prioritizing adaptation investments, and selecting appropriate strategies in coastal communities. The CARP recognized that many homes in Alameda are already affected by groundwater and given the findings in the newly published research, recommended further characterizing rising groundwater as a potential future hazard in Alameda's climate change vulnerability assessment.

The 2018 research revealed the City of Alameda is at-risk for rising groundwater in the face of climate change. However, due to sparse well data within city limits, and a strong tidal and precipitation influence within the Alameda soils, enhancements to the regional mapping were needed to characterize the shallow groundwater layer in Alameda. Staff engaged Silvestrum Climate Associates to develop a more refined model using geotechnical soil boring data collected throughout the City and the Oakland International Airport. This local groundwater model was then used to assess the groundwater surface response to various sea level rise scenarios. As the groundwater table rises, contaminants with the shallow groundwater will rise closer to the ground. The potential for contaminants to become emergent was also looked at.

The groundwater report finds that the areas at risk of future flooding increase by up to 25 percent when considering emergent groundwater, and in certain areas this flooding occurs well before coastal floodwaters overtop the shoreline. Rising groundwater, even before it is emergent, will affect below grade infrastructure such as building foundations, basements and utilities. **Figure 4-16** illustrates emergent groundwater under 24, 36, 66, and 108-inch sea level rise scenarios.

The groundwater report recommends adaptation solutions to include in the next update to the CARP, such as amendments to local building codes to address floodproofing and guidance for homeowners regarding sump pumps. Other follow-ups to the groundwater report include, among other items, integrating the study's results into relevant chapters of the General Plan, further analyzing potential landfill risks, and updating the digital elevation model used in the groundwater mapping given recent changes in grade at the Corica Golf Course and other areas of recent land development.



Source: The Response of The Shallow Groundwater Layer and Contaminants to Sea Level Rise, 2020.

Figure 4-16 Map depicting emergent groundwater for 24, 36, 66 and 108 inches of sea level rise

Flood Risk Assessment

If 100-year floodwaters as modeled on the FEMA FIRMs were to enter along the northern shoreline's 1,100ft long span of entry behind the Webster and Posey Tube portals, they would extend southerly down Webster Street to the intersection of Atlantic Avenue by the College of Alameda, flooding the tubes as well as affecting commercial businesses, and to a lesser extent residential buildings. While land elevation ranges between 5 ft and 10 ft NAVD88 within this flood zone area, elevations of developed properties are generally between 7 ft to 10 ft NAVD88, meaning that depth of flooding would be limited to 3 ft or less for these properties (depending on the location) at the 100-yr flood event. The tubes however would be more severely affected, as they descend to a depth such that the top of the tubes is at least 40 ft beneath the northern shoreline ground surface. In a coastal flood event waters would enter the tubes via the Webster and Posey portals and the extent/level of flooding within the tubes themselves would likely depend on the elevation of floodwaters during the event and the amount of time the tubes were exposed to it.

Along the eastern shoreline, the 350 ft long entry span for the 100-year flood places roughly 250 residential homes in the Fernside Boulevard / Liberty Avenue neighborhoods within the flood zone. Ground elevation ranges between 8 ft and 10ft NAVD88 in this area, meaning flooding at this event would be limited to a depth of 2 ft or less for these residential properties.

On Alameda Point, 100-year floodwaters entering along the 1.5 mile stretch of Main Street to the north and 1.6 mile stretch to the south would affect commercial businesses, industrial, residential, and City-owned properties, and federal lands such as the Least Tern nesting habitat on the former airfield tarmac. While elevations can be found as low as 5 ft NAVD88 on undeveloped properties within the Alameda Point flood zone, elevations of developed properties are generally between 8 ft to 10 ft NAVD88, meaning that depth of flooding would be limited to 2 ft or less at this event for developed properties with structures.

On Bay Farm Island, the interconnected 100-year flood zone spans a large enough area to include over 600 homes within it. Properties on Island Drive and Maitland Drive (south of the Chuck Corica Golf Course) are at the lowest ground elevations, as low as 2 ft NAVD88. This means the event on Bay Farm Island could result in a depth of flooding as great as 8 ft in these locations. However, several hundred of the homes included in the flood zone are along Lagoon System 1 North and are generally between 8 ft and 10 ft NAVD88 in elevation, meaning they would be subjected to a flood depth of 2 ft or less.

As described earlier, the current 100-yr flood event reaches the same elevation as a future TWL scenario of 42 in would, and therefore similar flood depths/impacts would be expected for both scenarios.

Note that roadways serving the areas described above would also be flooded to various depths depending on the road elevations. Roadways in the northern shoreline, eastern shoreline, and Alameda Point areas will all experience flooding to a different degree. Similarly, the three major roadways that provide egress from Bay Farm Island to the main island (and Oakland via Doolittle Drive) will experience flooding to various degrees. This is explained in further detail in the detailed flood and sea level rise risk assessment **Appendix F** and summarized below. Priority Coastal Inundation Locations are summarized in CARP and reproduced in **Appendix G**.

When floodwaters do occur, they result in the flooding of buildings, yards, and streets and can cause loss of use and damage of contents of residences, commercial establishments, schools, and other buildings. Floodwaters can damage underground utility boxes, prevent emergency circulation if streets are blocked, and release of hazardous material leachates. Recovery efforts may include removal of water, mud and debris; removal of moldy building material; repair of salt water damage to electrical and telecom facilities; and replacement of goods and furniture stored in low-lying areas.

Flooding affects natural shorelines as well. When erosive issues are at play from floodwaters, the underlying berm fill material that the shoreline is composed of is eaten away and the integrity of the shoreline is compromised. The effects are less pronounced with hardened shorelines such as riprap or seawalls. With natural shoreline areas like the northern shoreline of Bay Farm Island, the erosion becomes pronounced over time because there are not large boulders present to buffer the wave energy. In turn, the protective distance between homes and the waterfront is lessened and the potential for coastal flooding moving inland increased.

Increased flooding from sea level rise and rising groundwater levels can, depending on site-specific conditions, mobilize and release some of the contaminants in the ground, potentially creating exposure pathways, or increasing risk of exposure. Contaminated lands within Alameda are the result of previous land uses, such as manufacturing, that involved the use, storage, or disposal of hazardous wastes. Sites were identified, and the responsible entities are in the process of assessing or cleaning them up to meet current environmental and public health standards. A two-pronged strategy is needed to increase Alameda's resilience to contaminated lands: 1) all citizens and businesses should properly dispose of waste products to prevent future contamination, and 2) the City should assess timelines for cleaning up existing contaminated lands with regard to the potential for releases from increased flooding due to rising sea and groundwater levels.

High winds associated with storms can damage or knock down trees onto streets, power lines or buildings. Storms combined with high tides can cause coastal erosion, beach loss, habitat loss, shoreline street damage, shoreline trail damage, and marina damage.

Tsunamis

Hazard Description

Tsunami waves are triggered by ground displacements from large underwater earthquakes or landslides.[6] Tsunami waves do not "break" when they reach the shore like normal waves, instead they rush ashore like a fast-rising tide with powerful currents that extends much farther inland than normal tides. Even small tsunamis are associated with extremely strong currents capable of knocking someone off their feet.

Tsunamis impacting Alameda can result from offshore earthquakes within the Bay Area, or from distant offshore subduction faults such as those in the Pacific Northwest, Alaska, Japan and South America. Alameda will have several hours warning time for tsunamis generated in distant locations. Local tsunamis can also be generated from offshore strike-slip faults within the Bay Area and would provide little warning time. However, these faults are not likely to produce significant tsunamis because they move side to side, rather than up and down, which is the displacement needed to create significant tsunamis. They may have slight vertical displacements, or could cause small underwater landslides, but overall there is a minimal risk of any significant tsunami occurring in the Bay Area from a local fault. The greatest risk to Alameda is from events in the Cascadia subduction zone and the Aleutian Islands. These events could

[6] See: USGS, What are tsunamis?

generate significant tsunami waves that would reach Alameda within a few hours, providing short time for evacuation.

Historic Tsunamis

Over 70 tsunamis have been observed or recorded within the San Francisco Bay in the past 200 years, but none have caused significant damage in Alameda. Only two were recorded in the vicinity of Alameda before 1946. One of questionable record was in 1868 with a latitude and longitude in the Bay near Oakland Airport, listed as 4.5 feet, plus a sighting of unknown height at Government (Coast Guard) Island. Another was recorded in 1898 in Oakland at 0.31 feet.

Since 1946, when record keeping increased, there have been 30 tsunamis within the San Francisco Bay, and of those, about half have been recorded in Alameda. Recorded heights in Alameda have ranged from 0.02 feet to 0.51 feet. Most records are under 3 inches. There are no reported inundation run-ups within the Bay.

There have been two tsunamis in this time period that have caused damage within the San Francisco Bay, including the 1964 Alaskan event (M9.1) which caused widespread damage to the West Coast, including $2.2M in recorded damage and water heights up to 1.52 feet in the San Francisco Bay Area and Half Moon Bay and one death in Bolinas. The other major earthquake was the 2011 Tohoku (Japan) event (M8.9) which caused $125,000 damage at the Berkeley Marina and had water heights up to 1.50 feet. This tsunami caused at least $48M statewide, but resulted in only a non-destructive 6-inch wave along the shoreline of Alameda. **Figure 4-6** contains a detailed list of all tsunamis that have been measured in Alameda or Oakland, along with measurements taken elsewhere in the Bay Area.

Table 4-6 Tsunamis in the San Francisco Bay with Measurements Recorded in Alameda

Year	Location Name	Latitude	Longitude	Distance From Source (km)	Travel Hours	Maximum Water Height (m)
1946	ALAMEDA, CA	37.79	-122.27	3545	5:54	0.2
1952	ALAMEDA, CA	37.79	-122.27	7601		0.02
1952	ALAMEDA, CA	37.79	-122.27	6003	8:57	0.4
1957	ALAMEDA, CA	37.79	-122.27	4388	6:10	0.18
1960	ALAMEDA, CA	37.79	-122.27	9787	15:39	0.31
1964	ALAMEDA - NAVAL AIR STATION, CA	37.79	-122.27	3130	5:30	0.8
1968	ALAMEDA, CA	37.79	-122.27	7727		0.1
1992	ALAMEDA, CA	37.79	-122.27	337		0.04
1994	ALAMEDA, CA	37.79	-122.27	7265		0.04
2006	ALAMEDA, CA	37.79	-122.27	8402		0.04
2010	ALAMEDA, CA	37.79	-122.27	9635	15:10	0.12
2011	ALAMEDA, CA	37.79	-122.27	7939	10:49	0.51
2012	ALAMEDA, CA	37.79	-122.27	1833	4:08	0.11
2015	ALAMEDA, CA	37.79	-122.27	9304	14:49	0.06
2021	ALAMEDA, CA	37.79	-122.27	3295		0.06

Source: National Geophysical Data Center / World Data Service (NGDC/WDS): Global Historical Tsunami Database. National Geophysical Data Center, NOAA. http://dx.doi.org/10.7289/V5PN93H7, accessed 1/21/22

Recent studies of Tsunami conducted by the United States Geologic Survey (USGS) Science Applications for Risk Reduction (SAFRR) tsunami scenario also examine paleo tsunami.[7] This study looks back in geological time by using core sampling and other means to identify tsunami events before record keeping. Although there has not been an impact or any major devastation from tsunami in more than 100 years, geologic study suggest that significant tsunamis have impacted the San Francisco Bay Area in the past and are likely to happen again.

Future Tsunamis

Although tsunamis are rare events that have not historically caused significant damage for Alameda, future events could have significant consequences, including the complete inundation of Bay Farm Island and significant inundation of the Main Island. Damage to marinas, ships and piers, low-lying homes, and other facilities within the tsunami inundation zone would be catastrophic.

Because the largest potential tsunamis have likely not yet occurred in Alameda County, the state tsunami program developed a suite of maximum credible tsunami scenarios as part of their tsunami inundation mapping project for local evacuation planning. This information is displayed below in **Figure 4-17**, which is also taken from the City of Alameda Tsunami Evacuation Playbook (No. 2017-Alam-05) developed by the National Tsunami Hazard Mitigation Center. Tsunami heights range from 3-4 feet above mean sea level for a local tsunami source to a maximum of 16 feet for a magnitude 9.2 Central Aleutian (Alaska) earthquake. The inundation from these events is dependent in part by the geography of the shoreline and whether the tsunami wave arrival coincides with high or low tide. For reference, the 100-year flood discussed in the previous section is mapped at about 7 feet above Mean Sea Level.

These are important scenarios for emergency managers to prepare for as there could only be tens of minutes to evacuate or just a few hours to conduct response or evacuation activities before a tsunami arrives.

[7] USGS, The SAFRR (Science Application for Risk Reduction) Tsunami Scenario

<u>Modeled Tsunami Scenarios</u>: Because very large tsunamis are infrequent and the likelihood that the largest potential tsunamis have not yet occurred in Alameda County, the state tsunami program developed a suite of maximum credible tsunami scenarios as part of their tsunami inundation mapping project for local evacuation planning. The general tsunami wave height for key locations from these scenarios are provided below. As identified in the historical tsunami table, the largest tsunamis could occur from large earthquakes in the Alaska-Aleutian Islands region, or from a local fault or landslide offshore.

Tsunami Source Scenario Model Results for the San Francisco Bay Area

<u>Near shore tsunami heights (flow depths) for both local and distant source scenarios, in FEET above Mean Sea Level.</u> NOTE: The projections do not include any adjustments for ambient conditions, such as storm surge and tidal fluctuations, and model error (it is very important to note this difference, as those numbers can increase the projected water height during an event).

	TSUNAMI SOURCES	Approximate Travel Time	Pacifica	Ocean Beach	Black Point-Aquatic Park	Candle-stick Park	Alcatraz Island	Treasure Island	Yerba Buena Island	Redwood City	Alameda	Richmond	Mare Island	Saucilito	Boliinas
Local Sources	M7.3 Point Reyes Thrust Fault	10-15min	7	6	4	3	4	3	3	4	4	4	3	6	8
	M6.6 Rodgers Creek-Hayward Fault	10-15min	2	2	2	2	2	2	2		3	3	3	3	
	M7.1 San Gregorio Fault	10-15min	4	4	3	3	3	3	3		4	3	3	3	
Distant Sources	M9 Cascadia-full rupture	1hr	4	5	3	3	3	4	3		4	3	3	4	4
	M9.2 Alaska 1964 EQ	5hr	13	12	7	4	6	5	6		9	7	3	8	10
	M8.9 Central Aleutians I	5hr	9	11	6	4	6	5	4	4	9	7	3	7	7
	M8.9 Central Aleutians II	5hr	5	6	5	3	5	4	4		5	4	3	5	7
	M9.2 Central Aleutians III	5hr	18	22	11	6	10	8	7	5	16	10	4	10	19
	M8.8 Kuril Islands II	9hr	3	3	3	3	3	3	2		5	3	3	4	3
	M8.8 Kuril Islands III	9hr	4	4	3	3	3	3	3		4	3	3	4	5
	M8.8 Kuril Islands IV	9hr	5	5	3	3	3	3	3		4	3	3	4	5
	M8.8 Japan II	10hr	5	5	4	3	3	3	3		6	3	3	3	4
	M8.6 Marianas Trench	11hr	3	3	3	3	3	3	3	4	3	3	3	6	3
	M9.5 Chile 1960 EQ	13hr	5	6	3	3	3	3	3		5	4	3	5	5
	M9.4 Chile North	13hr	4	5	4	3	4	4	4		6	3	3	4	5
	Maximum Runup - Local Source		8	6	3	3	4	4	4	4	5	4	3	7	9
	Maximum Runup - Distant Source		20	24	12	6	12	10	9	6	18	10	4	11	22

Figure 4-17 Inundation Depths in Feet based on Tsunami Scenarios from Local and Distant Sources

The Tsunami Hazard Area Map shown on **Figure 4-18** shows areas (in yellow) of maximum tsunami runup from a suite of extreme, yet realistic, tsunami sources with an average 975-year return period, or inundation with a 5 percent chance of occurring in a 50-year period.[8] It is intended for local jurisdictional coastal tsunami hazard planning uses only.

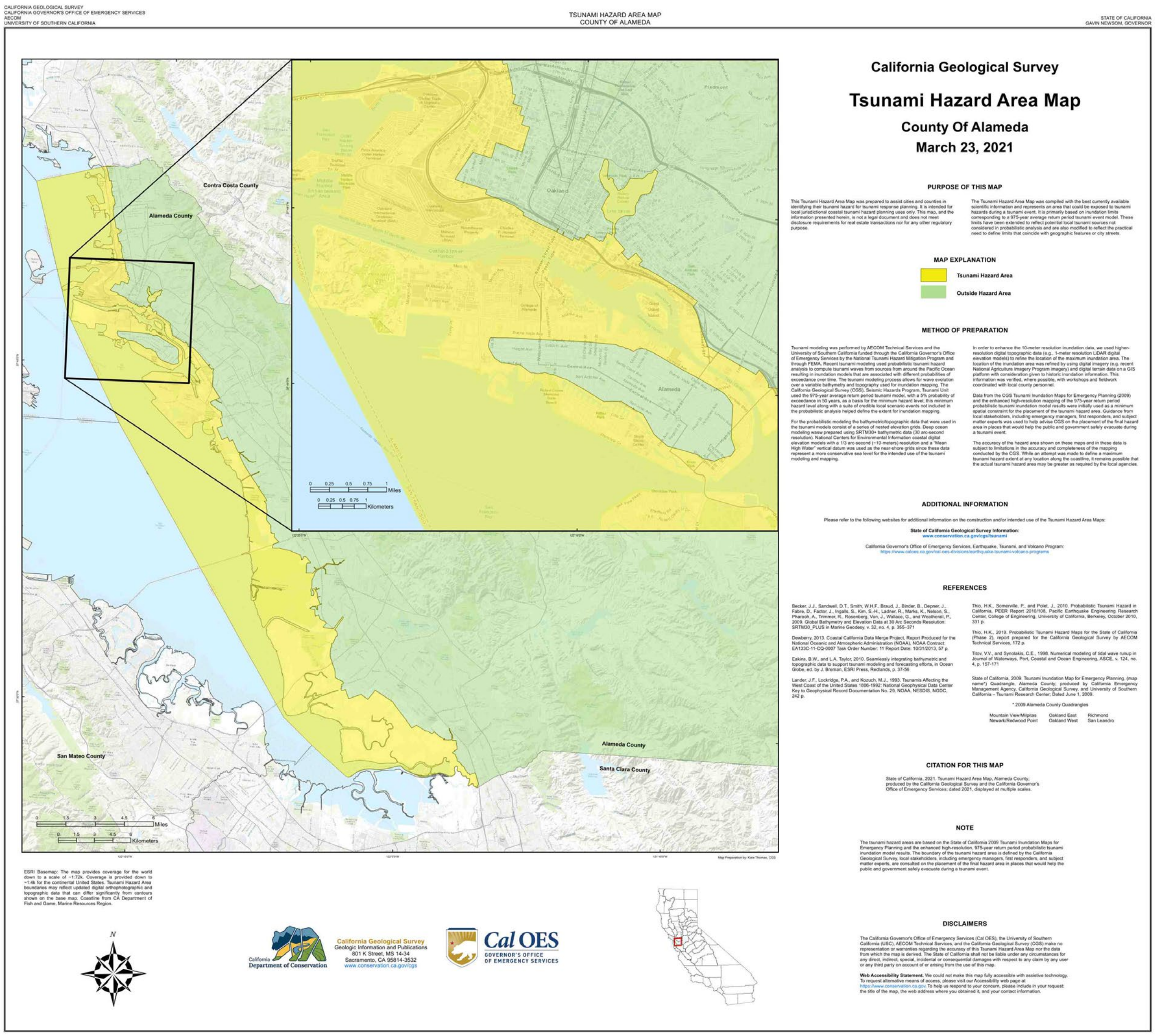


Figure 4-18 Tsunami Hazard Area Map

Climate Change and Tsunamis

Climate change will exacerbate tsunami hazards. Rising sea levels will lead to more tsunami runup. Just as a high tide affects inundation levels, so does sea level rise, causing the maximum height of a Tsunami runup to increase.

[8] State of California, 2021, Tsunami Hazard Area Map, Alameda County; produced by the California Geological Survey, the California Governor's Office of Emergency Services, and AECOM; dated March 23, 2021, mapped at multiple scales.

Tsunami Risk Assessment

A significant tsunami event would inundate large portions of Alameda main island and, in the worst-case scenario, would completely inundate Bay Farm Island. Inundation at this level would destroy homes, businesses, and city infrastructure, causing billions of dollars in damage and possible loss of life and loss of population due to displacement brought on by the damaging event.

Even where flooding and inundation are not a significant tsunami hazard for a particular event, the strong and erratic currents induced by the Tsunami can still lead to substantial damage. Areas that are particularly exposed to Tsunami current hazards are ports, harbors, and marinas. The 2011 Japan tsunami caused widespread damage to harbors along the California coastline and within the San Francisco Bay; these effects were almost exclusively due to strong currents. A Tsunami entering the San Francisco Bay accelerates as the wave is forced into the narrow estuary channel between Alameda and Oakland, causing damaging currents to accelerate and intensify. Piers and boats may be ripped from their moorings, causing damage in the millions of dollars in loss, as was the case with the Berkeley Marina and Santa Cruz Harbor during the 2011 Tsunami event. Although Tsunami events that may impact Alameda are rare, any tsunamis that enters the Bay pose a risk to marinas, beaches, and low-lying areas that regularly flood.

Evacuation Planning

If a tsunami is expected, the City would issue tsunami warnings to alert the public of areas that would need to be evacuated based on the Tsunami Playbook. Notifications would come from AC Alert, NextDoor, Facebook, broadcast TV, radio, wireless emergency alerts and reverse 911 calls, as well as directly from the U.S. Tsunami Warning System (https://tsunami.gov).

Central Avenue is the highest point in Alameda, and community members are encouraged to walk or bicycle to the center part of the main island or drive/bike beyond I-880. Community members west of Grand Street will exit through the tubes, and east of Grand Street will exit over Park Street, Miller-Sweeney, and the High Street Bridge. Bay Farm Island will exit via Doolittle or Ron Cowan Parkway by car or bus. Community members on Bay Farm Island can also bicycle or walk to the main island. Vertical evacuation to multi-story stable structures is an option if it is not safe to evacuate. Contraflow travel lanes will be used to expedite evacuations. Community members can also support traffic flow off the island by minimizing the number of cars sued to evacuate. Evacuation from Alameda into Oakland will be coordinated between the Alameda Police and Oakland Police to route traffic out of Alameda and through Oakland towards safety and out of identified danger zones. For boaters, it is not recommended to evacuate in a boat offshore. Instead, it is safer to keep the boat docked, since a boat would be difficult to navigate and would need to stay offshore in water of at least 180 feet in depth for over 24 hours. Detailed information about evacuation routes and their capacity and viability can be found in the Tsunami Emergency Annex of the City’s Emergency Operations Plan.

Due to the extreme risk tsunamis present for Alameda, the National Tsunami Hazard Mitigation Program has supported the development of tsunami response “playbooks” to areas with the highest risk of tsunami impacts. One such playbook was developed for the City of Alameda (California Tsunami Evacuation Playbook No. 2015-Alam-05), which provides tsunami-specific maps, guidance about in-harbor hazards, and plans to help emergency management officials respond to tsunamis of different sizes and distances from the California coast. The map depicted in **Figure 4-19**, taken from the City of Alameda Tsunami Playbook, identifies the Maximum Phase Tsunami Evacuation Zone for Alameda. In 2013, there were an estimated 39,515 Alameda residents in the maximum tsunami hazard zone, the highest residential exposure for one city to tsunami hazards in California.[9] This number has certainly increased with the population growth of the city since 2013 and the ongoing development at Alameda Point.

A response “Playbook” has been developed to assist the City of Alameda emergency management staff in making critical decisions about evacuation notification. Evacuation areas are based on expected run up, plus a margin of error, for a Tsunami generated from local or distant earthquake events.

There are four phases of evacuation scenarios in the “Playbook”, with Phase One being evacuation of the shoreline and harbors up to the Maximum Evacuation Phase, which effects large areas of the City**.** **Figure 4-19** shows a map of the four phases and they are described below.

- Phase 1 evacuates beaches, harbor docks/piers and boats. Strong currents and potential scour are expected in harbors. Mitigation actions include encouraging the maritime community to improve the harbors to mitigate the risk of damage due to the threat of Tsunami and make use of the Maritime Response Playbook Guidance documents.
- Phase 2 evacuates areas outlined in red on the map. The zones of inundation shown are similar to that of flooding caused by storms plus king tides and therefore mitigation actions to decrease flooding damage will also address tsunami inundation.
- Phase 3 evacuates areas outlined in red on the map. Mitigation actions include public education, utilizing the mass notification system and working closely with the media to alert the public. Inundation of this magnitude is generally precipitated by an earth quake occurring in the Alaskan-Aleutian subduction zone.
- Maximum Phase evacuates areas are outlined in red on the map. Mitigation actions include public education, utilizing the mass notification system and working closely with the media to alert the public. Inundation of this magnitude is generally precipitated by an earth quake occurring in the Alaskan-Aleutian subduction zone.

[9] Wood N, Ratliff J, Peters J, Shoaf K (2013b) Population vulnerability and evacuation challenges in California for the SAFRR tsunami scenario, chap. I. In: Ross SL, Jones LM (eds) The SAFRR (Science Application for Risk Reduction) tsunami scenario, U.S. Geological Survey Open-File Report 2013-1170

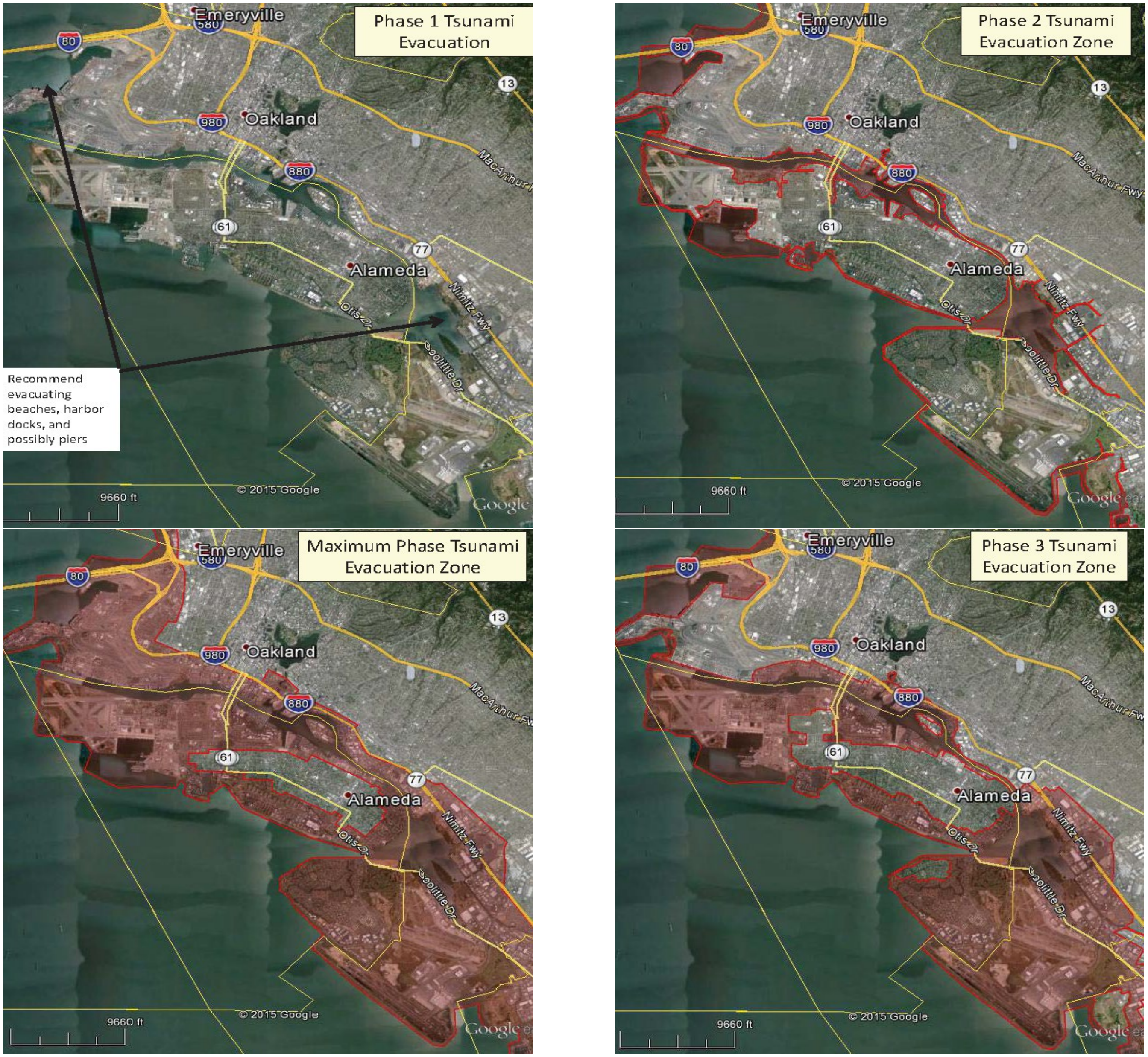
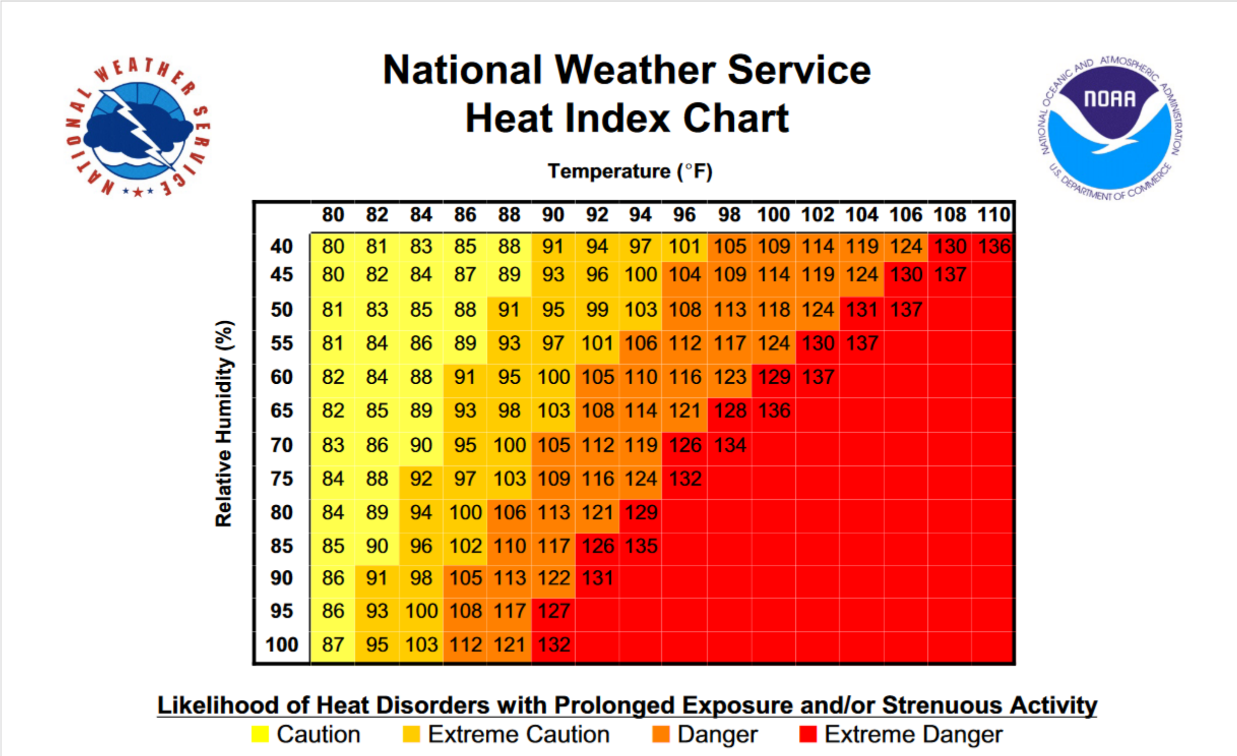


Figure 4-19 Tsunami Evacuation Phases

Heat

Extreme heat events are expected to increase in frequency, severity and duration in Alameda due to climate change with an increased number of extreme heat days and nights, increased temperatures over extreme days and greater duration of extreme heat events. Extreme heat events impact all of Alameda and can be exacerbated by Alameda's relatively high average maximum relative humidity (California Energy Commission, 2018).

The heat index shown in **Figure 4-20** is an accurate measure of how hot it really feels when the effects of humidity are added to high temperature.



Relative Humidity (%) \ Temperature (°F)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Figure 4-20 National Weather Service Heat Index ChartAccording to Cal-Adapt[10], an Extreme Heat day is defined as a day in April through October when the Maximum Temperature exceeds the location's Extreme Heat Threshold, which is calculated as the 98th percentile of historical maximum temperatures between April 1 and October 31 based on observed daily temperature data from 1961–1990. For Alameda, the Extreme Heat Threshold is 89º F. As shown in **Table 4-7**, between 1961 and 1990, Alameda averaged three Extreme Heat Days per year when daily maximum temperature was above 89° F. According to the National Weather Service, daily maximum temperature exceeded 89° F 142 times between 1970 and 2021 at the Oakland Museum weather station. Under a medium emissions scenario, Alameda is projected to experience an average of six Extreme Heat Days per year by mid-century and eight by end of century.

Cal-Adapt defines a Warm Night as a night during which the minimum temperature does not fall below the 98th percentile of historical overnight minimum temperatures for a place, computed using data from April through October for 1961 to 1990. For Alameda, the Warm Night Threshold is 61.5° F. As shown in **Table 4-7**, between 1961 and 1990, Alameda averaged five Warm Nights per year when daily minimum temperature was above 61.5° F. Under a medium emissions scenario, Alameda is projected to experience an average of 25 Warm Nights per year by mid-century and 46 of end of century. Warm nights are concerning because buildings do not naturally cool down when overnight temperatures are warm, thereby potentially increasing overnight energy consumption for cooling and producing public health impacts such as heat stress and even excess mortality. Warm nights can also negatively impact ecosystems and water supplies, particularly snowpack.

10 https://cal-adapt.org/tools/extreme-heat/

Table 4-7 Number of Extreme Heat Days and Warm Nights per Year in Alameda

Timeframe	Number of Extreme Heat Days per Year when daily maximum temperature is above 89° F	Number of Warm Nights per Year when daily minimum temperature is above 61.5° F
Modeled Historical (1961-1990)	3	5
Mid-Century Projection (2035-2064)*	6	25
End-Century Projection (2070-2099)*	8	46

*Projections assume a medium emissions scenario (RCP 4.5 from the Fifth Intergovernmental Panel on Climate Change (IPCC) Assessment Report on Climate Change): a scenario where GHG emissions peak by 2040 and then decline. In California, annual average temperatures under this scenario are projected to increase 2°C - 4°C by the end of this century, depending on the location.

The National Weather Service has created the HeatRisk forecast which provides a quick view of heat risk potential over the upcoming seven days.[11] The heat risk is portrayed in a numeric (0-4) and color (green/yellow/orange/red/magenta) scale which is similar in approach to the Air Quality Index (AQI) or the UV Index. During heat or extreme heat events, local National Weather Service offices may issue heat-related messages as conditions warrant. Such messages include:

- Excessive Heat Outlook: Issued when the potential exists for an excessive heat event in the next three to seven days. An outlook carries a minimum 30 percent confidence level that the event will occur.
- Excessive Heat Watch: Issued when conditions are favorable for an excessive heat event in the next 12 to 48 hours. A watch is given when the level of confidence that the event will occur reaches 50 percent or greater.
- Excessive Heat Advisory: Issued when an excessive heat event is expected in the next 36 hours. An advisory is used for a less severe event that is not assumed to be life-threatening, when caution is advised to mitigate the event's impact.
- Excessive Heat Warning: The most serious alert, issued when an excessive heat event is expected in the next 36 hours, or such an event is occurring, is imminent, or has a very high probability of occurring. A warning assumes the potential for health consequences due to extreme heat.

More extreme heat events represent a major public health risk that can cause heat exhaustion, stroke, difficulty breathing, and even death. These negative impacts are particularly acute for the economically disadvantaged, the transit-dependent, the very young, the elderly, those in poor health, the homeless, and those who work or spend significant time outdoors. The impacts of extreme heat events will be most severely felt for residents with pre-existing health issues, that have limited access to cooling, and/or those who live in highly developed areas of Alameda that are mostly paved and surrounded by buildings constructed of dark (heat absorbing) materials without the cooling benefits of tree shade. This creates what is known as the heat island effect, which can increase the temperature locally during extreme heat events. Extreme heat may also cause pavement heave and damage to transportation infrastructure and functioning (Caltrans, 2018). Increasing extreme heat events also increase the risk of drought and wildfire, and increased use of air conditioning during heat waves will increase energy use and GHG

[11] National Weather Service Experimental HeatRisk: Identifying Potential Heat Risks in the Seven Day Forecast. Retrieved from: https://www.wrh.noaa.gov/wrh/heatrisk/?wfo=hnx

emissions associated with energy use. While extreme heat events are less dramatic than other hazard events, they are potentially deadlier. A California Energy Commission study indicates that over the past 15 years, heat waves have claimed more lives in California than all other declared disaster events combined.

When heat is combined with air pollution impacts, such as elevated ozone levels and wildfire smoke, the impacts are exacerbated. In addition, Alamedans are inexperienced in dealing with extreme heat and wildfires and therefore lack adequate preparation. Others lack resources to purchase air conditioning. More energy use for air conditioning results in increased costs, further affecting those with limited resources. It also increases GHG emissions, which further affects climate change and its associated impacts.

Drought

Increasing average daily temperatures, decreasing snowpack, and “boom or bust” precipitation patterns are increasing California’s risk of more frequent and severe droughts. Drought impacts all of Alameda and statewide droughts have been declared in 1976-1977, 1987-1992, 2008, 2013-2016, and 2020-2021. The 2013–2016 drought resulted in the most severe moisture deficit in 1,200 years. The time series shown in **Figure 4-21** shows the percentage of land area in Alameda County within each drought category over time.

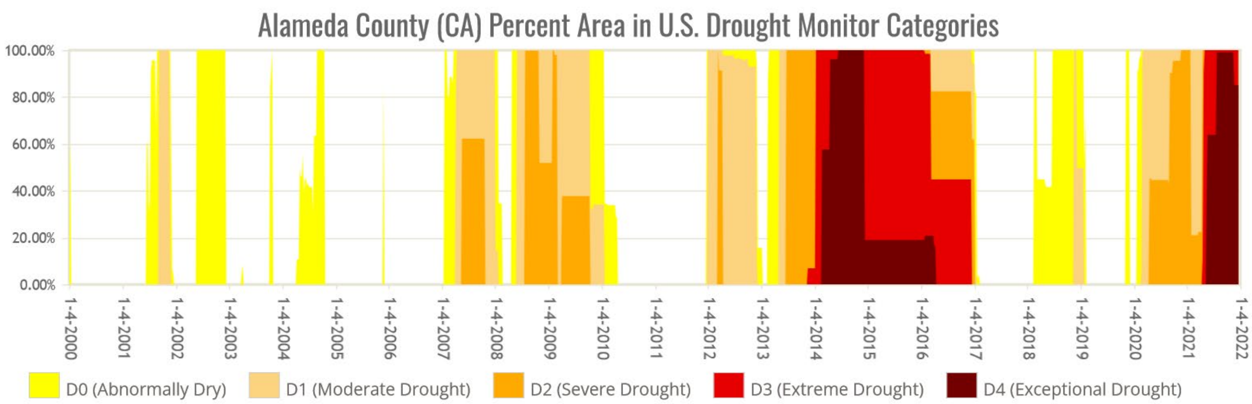


Figure 4-21 Alameda County Percent Area in U.S. Drought Monitor Categories

It can be difficult to predict the exact probability of a future drought due to their nature, but California is currently experiencing a drought in 2022. NOAA’s spring outlook, predicts prolonged, persistent drought in the West where below-average precipitation and above-average temperatures is most likely.[12] Although droughts are a natural part of our climate cycle in California and the primary driver for the occurrence of droughts in the state, studies have shown that warmer temperatures and lower precipitation associated with climate change increases the overall likelihood of extreme droughts in California.[13] Studies have also shown that precipitation deficits in California were more than twice as likely to yield drought years if

[12] NOAA. Spring Outlook: Drought to expand amid warmer conditions. March 17, 2022. Retrieved from https://www.noaa.gov/news/spring-outlook-drought-to-expand-amid-warmer-conditions
[13] Williams AP, Seager R, Abatzoglou JT, Vook BI, Smerdon JE, Cook ER. (2015). Contribution of Anthropogenic Warming to California Drought During 2012-2014. Retrieved from: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GL064924

they occurred when conditions were warm and that such confluences have increased in recent decades.[14]

Most rain and snow fall in California from November through April. This precipitation fills our reservoirs and aquifers that we use to supply homes, businesses and farms with water. It is also a vital resource for fish and wildlife that rely on our rivers and wetlands. The primary impact of recent droughts on the City of Alameda has been loss of, or decreased health of, landscaping material and trees in the City's parks and street rights-of-way. This may contribute to more downed trees during future storms. Long term concerns are a lack of adequate water for drinking and irrigation.

Alameda – along with all of California and the western United States – is currently entering into extreme drought conditions after the second year in a row of below average precipitation. **Figure 4-22** shows the California Drought Monitor for August 2021, 2015 and 2009. In August 2021, Alameda and most of the Bay Area were classified as "Exceptional Drought" conditions.

[14] Diffenbaugh NS, Swain DL, and Touma D. (2015) Anthropogenic warming has increased drought risk in California. Retrieved from: https://www.pnas.org/content/112/13/3931

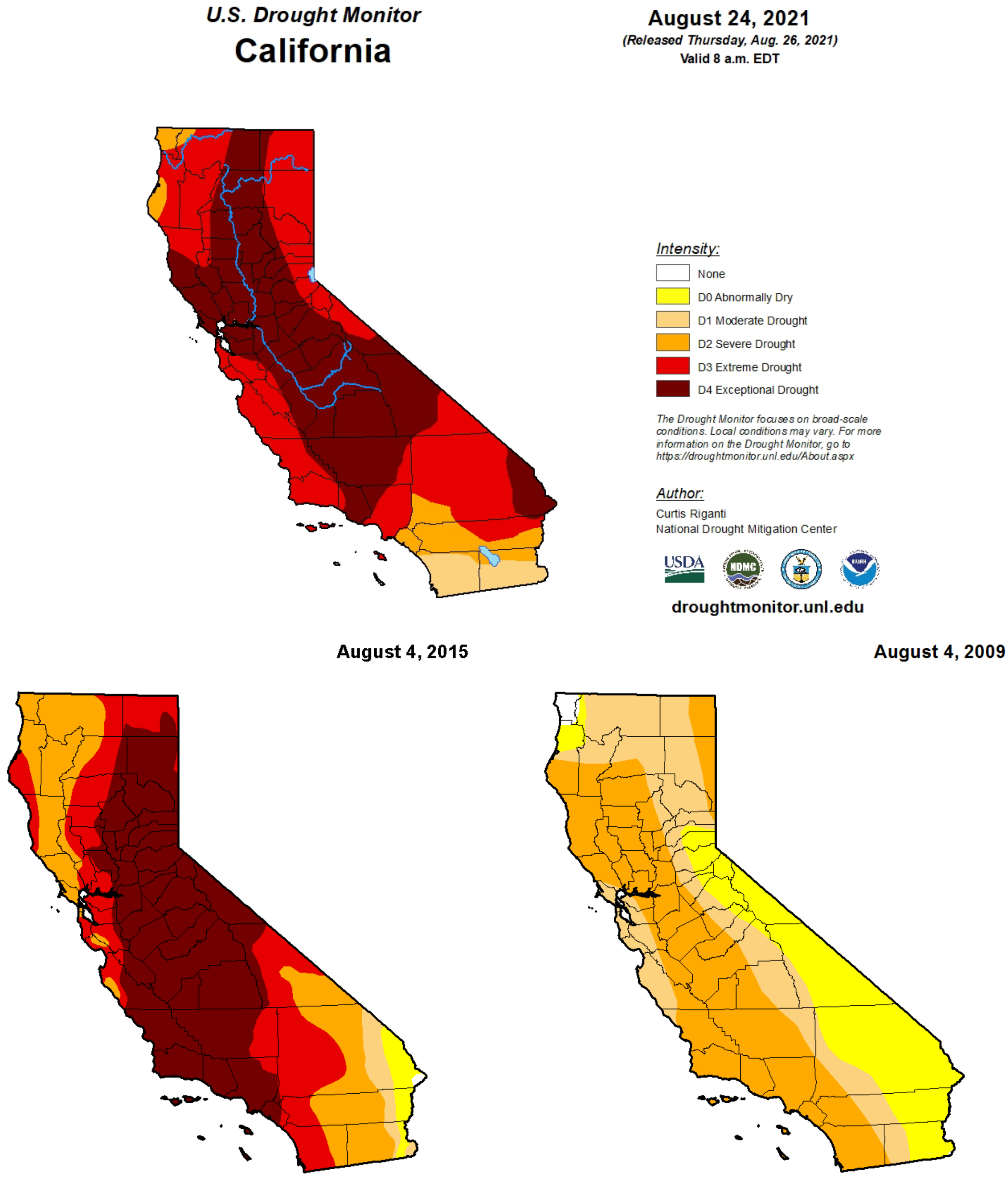


Figure 4-22 California Drought Monitor for August 2021, 2015, 2009

In response to worsening drought conditions, EBMUD called for voluntary 10 percent reduction in water use. In July 2021, Governor Newsom also called for 15 percent voluntary reduction by urban water users statewide. As this drought progresses, more significant water reduction measures may become necessary. Scientists believe we are in the beginning stages of a historical drought. All of California has been in drought conditions since late April 2021, and 88 percent of the state has been experiencing extreme drought or exceptional drought since late July 2021. Record-low water levels at the state's reservoirs have forced curtailment of hydro power production from hydroelectric dams, an important source of power for Alameda Municipal Power.

Ninety percent of Alameda’s water supply—provided by EBMUD—comes from the Mokelumne River watershed in the Sierra Nevada; the remaining 10 percent is runoff from watershed lands in the East Bay. Thus, Alameda’s drought vulnerability is tied to the vulnerability of EBMUD’s water supply system. Rising temperatures that reduce snowpack also pose a major risk to EBMUD’s water supply. Additionally, EBMUD relies on over 15 miles of aqueducts and pipes that transport water across the Sacramento-San Joaquin River Delta ecosystem, which has become increasingly vulnerable to flooding, landslides, and earthquakes. Both the quality and quantity of potable water can be impacted when the water supply distribution system is compromised. For example, in September 2017, an unprotected cross connection from an irrigation line impacted the quality of water supplied to hundreds of Alameda homes and businesses.

According to EBMUD’s (2014) Climate Change Monitoring and Response Plan, potential risks to water supply include:

- Increased demands for outdoor water use;
- Increased drought frequency, intensity, and duration;
- Decreased snowpack; and
- Changes in the timing of the Mokelumne River spring runoff.

Alameda can reduce its per capita water use to increase resiliency to drought by limited showers to 5 minutes, turning off the faucet when brushing teeth, only washing full loads of laundry, and planting drought resistant plants. Outdoor landscaping is one of the most significant uses of water and the place where residents and businesses can have the most impact in conserving water. EBMUD’s (2015) Urban Water Management Plan calls for a combination of rationing, conservation, and use of recycled water to satisfy demand through 2040. The City of Alameda has taken a number of measures to further reduce water usage, including, increasing composting, reducing irrigation of decorative lawns (resulting in 3.6 percent reduction), turning off fish cleaning spigots at Encinal Beach (alternative fish cleaning methods being explored), converting decorative lawns at city facilities and some parks to drought tolerant landscape, prioritizing fixing pipe leaks, converting irrigation clocks to rain sensitive clocks (resulting in 15 percent reduction).

Wildfire-Related Hazards

Drought conditions helped fuel another destructive wildfire season in California in 2021, burning more than 2.5 million acres, which is more than double the number of acres that burned on average in the previous five years to date.[15] The Dixie Fire in northeastern California 963,309 acres before being 100% contained on October 25, 2021 and became the second largest wildfire in California’s history behind last year's 1.03-million-acre August Complex as the largest fire in state history. While wildfires do not directly impact the City of Alameda, the impacts of smoky air from wildfires across the state have been regularly experienced in Alameda and public safety power shutoffs (PSPS) designed to prevent wildfire ignitions from power lines have the potential to cause power shut offs in Alameda, though none have been

[15] California Department of Forestry and Fire Protection

experienced to date and Alameda has redundant power feeds helping decrease the likelihood of shut-offs impacting Alameda.

Smoky Air

Breathing smoky air can have serious consequences for human health. Exposure to smoke is known to impact lung health and has been associated with respiratory infections and increased risk of death. Those who are especially vulnerable existing cardiovascular and respiratory ailments such as asthma, diabetes, pregnancy, young children, older adults, and those who work outdoors. Individuals with COVID-19, or recovering from COVID-19, are also at greater risk from smoke. The high unpredictability of wildfires and their impact on downwind areas heightens the vulnerability of Alamedans to wildfire risk. Furthermore, because wildfires spread so quickly and wind direction may suddenly change, there is little lead time to warn and prepare residents for wildfire smoke impacts. It is also difficult to predict the severity of wildfire smoke impacts or how long they are likely to last. Community members are generally taken by surprise and don't realize how hazardous air quality may be to their health.

Over the last decade wildfires have become increasingly frequent and intense and have impacted all of Alameda and the state. While wildfires do not occur within the City of Alameda, wildfires occurring outside the region can impact public health in Alameda. Winds can carry smoke from active wildfires into the region and wildfire smoke can reach hazardous levels in Alameda as measured by the U.S. Environmental Protection Agency's (EPA's) Air Quality Index (AQI). Air quality impacts from wildfires recently raised public awareness and concern beginning during the Camp Fire that occurred in fall 2018. During that event, air quality, measured by $PM_{2.5}$ (particulate matter with a diameter of 2.5 micrometers or less), was rated "hazardous for all groups" for 12 consecutive days, with the peak occurring on November 16, 2018, when "very unhealthy" levels were recorded at a monitoring station near Alameda (Bay Area Air Quality Monitoring District).

Table 4-8 below lists the number of Spare the Air Days that were called by the Bay Area Air Quality Management District because particulate matter (PM) was forecast to exceed national standards, as well as the number of days on which PM concentrations officially exceeded the state and federal health-based air quality standards. PM exceedance typically occurs because of winter time wood burning, but since 2020 has more commonly occurred in the summer as a result of wildfires. The Spare the Air Days shown in **Table 4-8** were called for the entire 9-county Bay Area, including the City of Alameda.

Table 4-8 Number of Spare the Air Days Issued for Excess PM Levels

Year	Spare the Air Alerts	National 24 Hour PM 10 Excess Days	CA 24 Hour PM Excess Days	National 24 Hour PM 2.5 Excess Days
2022	0	0	0	0
2021	5	0	0	2
2020	46	0	0	25
2019	3	0	5	1
2018	18	1	6	18
2017	28	0	6	18
2016	5	0	0	0
2015	17	0	0	6
2014	13	0	2	3
2013	33	0	6	13
2012	5	0	1	3
2011	12	0	3	8
2010	6	0	2	6

Source: https://www.sparetheair.org/understanding-air-quality/data-and-records/pm-data

The City of Alameda took the following actions in response to smoky air days to protect employees and the public:

- September 11, 2020 -the City of Alameda moved all city employees inside to work because of very unhealthy air quality
- September 27 through October 2, 2020, was a continuous spare the air period. The City allowed at-risk employees to work inside, and masks were available for the public and the employees.
- June 22, 2021, the Clean Air center was opened at the Main Library
- August 30, 2021, the Clean Air center was opened at the Main Library

There are no established climate projections for increased risk of wildfire smoke; the existing projections focus on determining areas susceptible to wildfires themselves and not specifically the downwind impacts. Nonetheless, increases in air temperature and the frequency and severity of droughts are likely to result in an elevated risk of more intense, prolonged, and/or large-scale fires throughout California, which could create conditions like those experienced in November 2018.

During a poor air quality event, the Bay Area Air Quality Management District provides air monitoring data for several constituents, including ozone and $PM_{2.5}$, that track smoke impacts. **Figure 4-23** shows the level of health concern associated with each AQI category. **Figure 4-24** shows the U.S. Air Quality Index Activity Guide provides ways to protect your health when particle pollution reaches unhealthy levels. Local air quality forecasts can be found at visit www.airnow.gov.

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Figure 4-23 AQI Basics for Ozone and Particle Pollution

Air Quality Index	Who Needs to be Concerned?	What Should I Do?
Good (0-50)	It's a great day to be active outside.	
Moderate (51-100)	Some people who may be unusually sensitive to particle pollution.	**Unusually sensitive people:** *Consider reducing* prolonged or heavy exertion. Watch for symptoms such as coughing or shortness of breath. These are signs to take it easier. **Everyone else:** It's a good day to be active outside.
Unhealthy for Sensitive Groups (101-150)	Sensitive groups include **people with heart or lung disease, older adults, children and teenagers.**	**Sensitive groups:** *Reduce* prolonged or heavy exertion. It's OK to be active outside, but take more breaks and do less intense activities. Watch for symptoms such as coughing or shortness of breath. **People with asthma** should follow their asthma action plans and keep quick relief medicine handy. **If you have heart disease:** Symptoms such as palpitations, shortness of breath, or unusual fatigue may indicate a serious problem. If you have any of these, contact your heath care provider.
Unhealthy (151-200)	**Everyone**	**Sensitive groups:** *Avoid* prolonged or heavy exertion. Consider moving activities indoors or rescheduling. **Everyone else:** *Reduce* prolonged or heavy exertion. Take more breaks during outdoor activities.
Very Unhealthy (201-300)	**Everyone**	**Sensitive groups:** *Avoid all* physical activity outdoors. Move activities indoors or reschedule to a time when air quality is better. **Everyone else:** *Avoid* prolonged or heavy exertion. Consider moving activities indoors or rescheduling to a time when air quality is better.
Hazardous (301-500)	**Everyone**	**Everyone:** *Avoid all* physical activity outdoors. **Sensitive groups:** Remain indoors and keep activity levels low. Follow tips for keeping particle levels low indoors.

Figure 4-24 Air Quality Guide for Particule Pollution

Public Safety Power Shut-offs (PSPS)

In recent years, power lines have been responsible for some of the most destructive wildfires in California history. In response, PG&E has begun to proactively cut power to (de-energize) electrical lines that may fail in certain weather conditions to reduce the likelihood that their infrastructure could cause or contribute to a wildfire. These shut-offs are called Public Safety Power Shut-offs (PSPS). A PSPS can leave downstream communities that rely on the de-energized power lines to be without power, causing hardships particularly for vulnerable and medically fragile populations. Because PSPS occur in response to high heat and wind conditions during wildfire season, they can leave residents without power at a time when air conditioning and clean air is needed the most. From 2013 to the end of 2019, California experienced over 57,000 wildfires (averaging 8,000 per year) and the three large energy companies conducted 33 PSPS de-energizations. Widespread and prolonged PSPS events in late fall 2019 led to customer confusion, anger and led to some customers, including medical baseline costumers, not being notified of PSPS events. In response, the California Public Utility Commission assessed the performance of PG&E, Southern California Edison and San Diego Gas and Electric in these PSPS events and made significant updates to the guidance about when and how to conduct PSPS outages.

Alameda has not been affected by PSPS outages to date, but could be in the future. While Alameda Municipal Power procures and provides power to customers in Alameda, electricity travels from power generation sources across the state to Alameda on PG&E transmission lines. Alameda receives power from two redundant transmission lines that enter Alameda from the South and from the North. Each transmission line is fully capable of carrying Alameda's electric load. The likelihood of both transmission lines being de-energized for PSPS simultaneously is considered extremely low.

Dam Breach Inundation

Dam breach inundation may result in human fatalities and casualties, damage to structures and infrastructure, economic impacts, and environmental impacts. The inundation maps shown in **Figure 4-25** and **Figure 4-26** show flooding that could result from a hypothetical failure of the Chabot and New Upper San Leandro Dams.[16] These maps do not consider the likelihood of such a failure, which is considered very unlikely. There have been no previous inundation events from either profiled dam. Both dams are owned and operated by EBMUD and have received a 'satisfactory' rating from the State of California Division of Safety of Dams (DSOD), the highest safety rating possible.

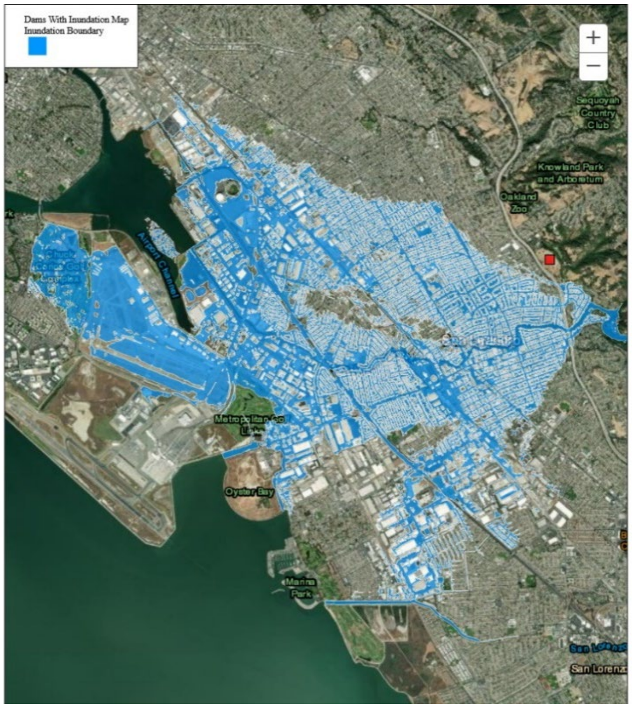


Figure 4-25 Chabot Dam Inundation Map

[16] California Division of Safety of Dams, Dam Breach Inundation Maps

Chabot Reservoir is a 10,350-acre-foot raw water storage facility operated by EBMUD in the cities of San Leandro, Oakland and Castro Valley.[17] The 135-foot high earthen Chabot dam and outlet works structure underwent a seismic upgrade to improve the performance of the facility during a large earthquake. Construction was completed in 2017. In the unlikely event of complete failure of the dam structure, Corica Park Golf Course, Godfrey Park and some residential properties along Beach Road, Maitland Drive and Garden Road on Bay Farm Island could become inundated as shown on **Figure 4-25**. The main island of Alameda would not be impacted.

Figure 4-26 Figure New Upper San Leandro Dam Inundation Map

Upper San Leandro (USL) Reservoir is a 42,000-acre-foot reservoir located upstream from Chabot Reservoir about 8 miles from downtown Oakland.[18] The USL Reservoir receives local runoff as well as imported Sierra Nevada water via the Mokelumne Aqueduct. Seismic evaluations concluded that the USL Dam Outlet Tower located in the Reservoir which conveys raw water to the USL Water Treatment Plant for distribution to EBMUD customers would sustain damage in a seismic event. The Tower was retrofitted to ensure safe operation of the structure in 2018. The earthen USL Dam was not determined to need seismic upgrades. In the unlikely event of complete failure of the dam structure, part of Bay Farm Island and the East Shore neighborhood on the Main Island could become inundated as shown on **Figure 4-26.**

[17] https://www.ebmud.com/about-us/construction-and-maintenance/construction-my-neighborhood/chabot-dam-upgrade/
[18] https://www.ebmud.com/about-us/construction-and-maintenance/construction-my-neighborhood/upper-san-leandro-usl-dam-outlet-tower/

Other Hazards Not Considered in this Plan

This plan focused on geologic and weather-related hazards impacting Alameda that can be in part addressed through upgrades to the physical environment. Hazards that are either not significant or don't fit within the scope of the plan are not included in our analysis. Many of these hazards are still addressed within the context of the City's emergency response planning efforts.

Lesser natural hazards for the City of Alameda include extreme cold and wind. While these hazards are important to plan for, and have occurred in Alameda, they present a much lower risk to life and property and the primary method to address them is through response planning, rather than pre-disaster mitigation. The record low temperature for Alameda was 26°F, set in December of 1972, during an unusual week-long cold snap below freezing.

Hazards caused by immediate human activity are not within the required scope of this Local Hazard Mitigation Plan. Such hazards include chemical spills, tanker spills, large urban fires, arson, pandemics, cyber-attacks, civil unrest, energy shortages, terrorism, and transportation incidents (airplane, truck, ship, ferry, pipeline and bus). However, the City learned through its citizen survey, conducted as a part of this update process, that the community is concerned about these potential issues and many are included in Alameda Emergency Response Plan. Also not included is accidental dredging damage to Alameda infrastructures in the Estuary and San Leandro Channel, including sewer, water, power, natural gas, communications, marinas, and transportation.